Skagit Power Development: Skagit River and Newhalem Creek Hydroelectric Projects
On the Skagit River
Newhalem Vic.
Whatcom County
Washington

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HISTORIC AMERICAN ENGINEERING RECORD

SKAGIT POWER DEVELOPMENT: SKAGIT RIVER AND NEWHALEM GREEK HYDROELECTRIC PROJECTS

HAER No. WA-24

Location: Upper Skagit River, Newhalem vicinity, Whatcom County, State of Washington.

Date of Construction: Project began in 1918, construction of last dam (Ross) was completed in 1961.

Present Owner: City of Seattle Lighting Department.

Present Use: Hydroelectric plant.

Significance: Developed over a 50 year time span by Seattle City Light, the Skagit River Hydroelectric Project consists of three large dams and power plants: Gorge, Diablo, and Ross. Associated with it is the small Newhalem Creek Hydroelectric Project. Many features of the individual plants were significant in being the first of their type, such as the power tunnel at Gorge in 1924, and some of the country's outstanding engineers were associated with the planning, design, and construction of the facilities. At the time of its construction in 1929, Diablo Dam was the tallest thin arch dam in the world, and Diablo Powerhouse had the world's largest overhead crane. In addition, Seattle City Light's emphasis on presenting a showcase for electricity and efforts at public relations were reflected in the project's design and are unique in the industry.

Historian: Nancy Farm Mannikko
June 1990.

Note: This report is part of the Skagit River and Newhalem Creek Hydroelectric Project, which was prepared as part of the Federal Energy and Regulatory Commission's (FERC) re-licensing of the Skagit River Project (FERC No. 553).

INTRODUCTION

At every waterfall two angels stay
One clothed in rainbows, the other veiled in spray.
The first the beauty of the scene reveals,
The last revolves the mighty water wheels,
And there those white-robed sisters ever stand,
Beauty and utility, hand in hand.[1]

The development of Washington's Skagit River for hydroelectric power was one of the most ambitious municipally-financed utilities projects of its day. Developed by Seattle City Light, the Skagit Hydroelectric Project consists of four power plants: three large facilities, Gorge, Diablo, and Ross, and one small plant, Newhalem. The challenges presented by the Skagit region were many. The Skagit River runs through some of the most rugged terrain in Washington state, a fact which presented daunting logistical and technological problems to those attempting to develop it. But there were challenges other than those presented by nature and the constraints of technology. The Skagit development was also at the center of a bitter struggle between public and private power advocates. Both sides had long recognized the Skagit's hydroelectric potential, and the battle to gain control of that region was characterized by political infighting and chicanery. Always at the center of the Skagit controversy was Seattle's Superintendent of Lighting, James Delmage ("J.D.") Ross, and whether Ross is viewed as a visionary or as a ruthless empire builder, the story of the Skagit is also the J.D. Ross story.

This report is both a general history of Seattle City Light's Skagit Hydroelectric Project and a specific technological history of Diablo Dam and Powerhouse. It begins by describing the geophysical features of the Skagit River valley and summarizing the early years of its exploration and settlement. The growth of hydroelectricity in Washington and the early years of Seattle City Light are reviewed, and the social, political, and economic context leading up to and influencing the development of the Skagit and the construction of Diablo Dam and Powerhouse are briefly examined. Seattle City Light's initial development plans for the Skagit and the construction of Gorge Dam and Powerhouse are detailed and dam construction and the role of civil engineering in dam design in the 1920s are reviewed. Finally, the history of Diablo Powerhouse and Dam and the careers of the two men who most influenced the construction, Superintendent of Lighting J. D. Ross and Lars Jorgensen, the civil engineer who designed the dam, are summarized. Because it is not possible to fully explore the multitude of complex issues involved in building the Skagit in a report as brief as this one extensive endnotes and bibliography follow the text. An equipment inventory for each facility is provided in the appendices.

Early Days on the Skagit

From where it rises in Beaver Lake in the Cascade Mountains in the Canadian province of British Columbia, the Skagit River flows south and then west through the state of Washington. Although the river itself is comparatively short, being approximately only 140 miles long, the Skagit's tributaries include the Baker, Cascade, Sauk, and Suiattle Rivers. Together they comprise the largest drainage basin in Puget Sound with an area of 3,105 square miles, of which 400 square miles lie in Canada. A Forest Service report describes glaciation as having "exerted a major influence on the Skagit River Valley" as the melting glacier which once filled the valley left deep deposits of alluvial material in the river bed. The terrain within the Skagit basin ranges from precipitous mountains of the northern Cascades with elevations of 8,000 feet in the east to the flat tidal marshes and sloughs of the Skagit delta to the west.[2]

Before the Skagit enters Puget Sound, the river spreads out into a delta and becomes a maze of sloughs, marshes, and multiple mouths. These mouths were choked with debris in the past and the river went largely unnoticed by early explorers along the Pacific Northwest coast. The first permanent white settlers did not arrive in the Skagit area until 1855. Samuel Calhoun is credited with being the first pioneer to recognize the rich agricultural potential of the Skagit delta. Calhoun erected dikes and drained coastal marshlands in 1863, and other farmers emulated his example. But two massive log jams a short distance upriver near the site of present day Mount Vernon discouraged settlers from travelling further upstream by boat. Travel on land was also arduous, with the sloughs and marshy ground rendering travel along the lower Skagit almost impossible.

The discovery of gold in the Fraser River valley in British Columbia and in eastern Washington in the 1850s, however, spurred efforts to explore the upper Skagit. The first expedition in the region occurred in 1858 when Major Van Bokkelen led a group of prospectors up the Skagit to Baker River. Soon after other groups of prospectors began travelling the Skagit and pressure mounted to have the log jams removed to make both steamboat travel and agricultural and industrial development upriver possible. Local citizens petitioned the territorial and federal governments for help in clearing the river, but in the end they had to fall back on local resources. In 1877 men working on the lower jam opened a 250-foot wide channel and by 1879 had succeeded in cutting a 120-foot channel through the upper jam. The lower Skagit, at least for navigation, had been subdued.[3]

The upper Skagit, which drops from an elevation of approximately 1600 feet near the Canadian border to 400 feet forty miles downstream proved to be a more difficult challenge. The fast-flowing river contained treacherous rapids. Sheer canyon walls extended along either side of sections of the upper Skagit and prevented the use of pack animals in many places. During the Skagit gold rush of 1880 prospectors often found it easier to travel down from Canada rather than follow the river inland from its lower reaches. The miners persisted in their efforts to establish a route along the upper Skagit, however, and by the mid 1890s they had established a reasonably good pack trail, often referred to as the "Goat Trail" due to its many switchbacks, from Marblemount to the upper Skagit. Miners created and widened portions of the trail through blasting, and volunteers constructed bridges to allow pack trains to travel to and from the mines on Ruby and Thunder Creeks.[4]

Along with the miners, a few intrepid homesteaders ventured into the North Cascades. The lack of arable land discouraged many settlers, but in 1898 the Davis family built a cabin at Cedar Bar near present day Diablo and established a farm that evolved into a hotel and guest ranch. The Davises catered originally to the miners and pack trains passing through on their way to claims further up the Skagit, but after much of the north Cascades became a National Forest in 1907 the Davis Ranch began providing lodging for sportsmen attracted by the trout fishing along the river. The upper Skagit coming under National Forest Service jurisdiction forced some settlers to leave the area when they were unable to prove up, i.e., satisfy government regulations for establishing validity, their homesteading claims. At the same time, however, the presence of the Forest Service meant that the trails and bridges of the Skagit became more systematically maintained.

Travel to the upper Skagit remained a time-consuming and occasionally difficult experience, but many of the early dangers had been eliminated. Instead of fording flooded creeks or scrambling along precipitous trails choked with devils-club, travellers benefitted from improvements made by the Forest Service in the 1910s. Working with hand tools and packing all materials in on horseback (or, in some cases, on their own backs), the Forest Service rangers and trail crews constructed lookout towers, ranger stations, bridges and trails.[5] Bridges constructed were no longer rough-hewn log affairs but rather solid, professionally designed structures. The crossing at Thunder Creek, for example, was built by Forest Service in 1913 and consisted of a timber and wire rope suspension bridge with a span of approximately 100 feet. The abrupt twists and turns of the Goat Trail through the Skagit Gorge made it impossible to pack the cable in on mules and so it was dragged and carried in by men.[6] Finally, telephone wire was strung from ranger station to ranger station and to the few homesteads on the upper Skagit. With the arrival of the Forest Service, the years of relative isolation had ended. When engineers and speculators began surveying the Skagit for sites for potential hydro-electric development, they travelled with relative ease on horseback and stayed at established guest houses and inns such the Davis Ranch and the Ruby Inn.[7] A canyon that had seemed too inaccessible for commercial hydroelectric purposes a few years earlier now appeared more promising.[8]

Growth of the Electric Utility Industry in Washington

Washington received its first commercial electricity in 1886, when Sidney Z. Mitchell and F.H. Sparling,[9] regional agents of the Edison Electric Light

Company, persuaded the Seattle City Council to grant them a twenty-five year franchise to build and maintain a central station system for incandescent light. Operating under the name of the Seattle Electric Light Company, Mitchell and Sparling constructed a power plant off Jackson Street between First Avenue South and Occidental Avenue, near an area of Seattle known today as Pioneer Square, where steam engines direct-connected to a dynamo generated the electricity. By the turn of the century, numerous small competing private electric companies operated plants in the Seattle area.[10]

The first commercial hydroelectric power in Washington was generated in Spokane in 1887. A 100 kilowatt Edison bipolar generator connected to a water turbine at a low head waterfall in what is now the center of Spokane signalled the birth of the Washington Water Power Company. The electricity generated powered the community's arc lighting system.[11]

At the same time that investor-owned electric companies were being established, a movement advocating the municipal ownership of utilities began to grow. Promoters of municipal ownership believed that if cities took control of all phases of power production, from initial generation to final distribution, they could generate electricity more efficiently and more cheaply than privately-owned firms. Seattle's 1869 city charter gave the city the authority to provide its own street lighting, but it was not until 1893 that a report to the mayor recommended formation of a municipal light company. The amended city charter of 1896 authorized municipal ownership of an electrical utility and on March 4, 1902, citizens of Seattle approved a $590,000 bond issue for construction of a municipal generating plant at Cedar Falls and Seattle became formally involved in the electric utility business.[12]

This development at Cedar Falls played a vital role in shaping the direction taken by future hydro-electric projects and in influencing political developments within the city. A young, self-trained electrical engineer, James Delmage Ross, walked into the office of Reginald H. Thomson, the City Engineer, and applied for the job of designing the plant. Ross had never designed a power station, but he managed to convince Thomson he could do the job. Ross's thirty-seven-year association with the Seattle Lighting Department had begun.

John Delmage Ross was born in Chatham, Ontario, in 1872. He enjoyed science and reportedly dabbled with experiments in electricity and chemistry, but his formal education ended after two years at the Chatham Academy, giving him the equivalent of a tenth grade education. His first job, obtained at the age of twenty, was as an elementary schoolteacher, an occupation he continued at for six years. In 1898 doctors diagnosed Ross as having lung trouble. He responded by joining the gold rush to the Yukon Territories. The rugged outdoor life apparently restored his health, although he failed to find gold, and he and a friend worked their way down the Pacific coast to Seattle. Raised in a strict Presbyterian home, one of Ross's first actions upon arriving in the city was to join a church, the same church City Engineer Thomson attended. When the city decided to build at Cedar Falls, Ross already had a friend in the engineering department.

After joining the Lighting Department in 1902 as an electrical engineer, Ross was promoted to Superintendent of Lighting in 1911 and remained with the department until his death in 1939. Ross identified so closely with the Lighting Department that not even being fired briefly, as he was in 1931, or being recruited by Franklin D. Roosevelt for two positions in the New Deal administration, first as a member of the Securities and Exchange Commission and later as administrator for the Bonneville Power Administration, could loosen his grip. In correspondence with the President, Ross made it clear that he could work for the New Deal only if he could retain his connections with Seattle City Light.[13]

Ross envisioned access to electricity as being every citizen's right and often compared it to sunlight and water. This vision of public power combined with his consummate political skills -- during Ross's tenure in office the City of Seattle had at least eight different mayors and half a dozen City Engineers, many of whom disagreed strongly with the policies Ross promoted, and Ross outlasted or outmaneuvered them all -- affected the development not only of the Skagit but also of the electric utility industry nationally. Ross's recognition of the importance of maintaining good relations both with the general public and with the news media led to the creation of the Skagit Tours in the late 1920s. These tours, during which tourists spent two days visiting an active hydroelectric construction site, were unprecedented in the industry and generated national attention.[14]

The first plant Ross designed at Cedar Falls included a rock-filled timber crib dam that raised the level of Cedar Lake fifteen feet, with power provided by two 1200 kilowatt generators. The demand for electricity quickly outpaced the supply, and in 1908 the city raised the crest of the dam six feet and added two 4000 kilowatt generators to the powerhouse. By 1910 the plant was again overloaded. Consultants' reports indicated that the presence of a glacial moraine made the Cedar Lake site unsuitable for a high masonry dam, but Seattle's Lighting and Engineering departments were under political pressure to increase the power supply quickly. These pressures proved irresistible, and in 1914 the city began construction of a 215-foot-high masonry dam at a location one and one-half miles downstream from the original dam. As the reservoir filled, it became apparent the project had indeed been undertaken too hastily. The north embankment of the reservoir leaked, and leaked badly. City engineers and the lighting department nervously debated how to seal the pool and consulted with outside experts, whose advice ranged from allowing the natural silting action in the reservoir to cure the problem to proposals that would have required completely draining the reservoir to implement.[15] Events quickly made the discussion moot. On December 23, 1918, the "Boxley blow-out" occurred. Water that had apparently percolated through the north bank caused flooding and mud slides, inundated the nearby town of Edgewick and the North Bend sawmill, and generated litigation which took years to resolve.[16] The dam upon which the Lighting Department had pinned its hopes rapidly became not simply an embarrassment but a major financial liability. Since that catastrophe, Cedar Falls has served as an exemplar for what not to do in future projects. The cautionary phrase that "it has a north bank like Cedar Falls," first used by Ross in August 1918 in describing Lake Cushman before the blow-out occurred, frequently proved sufficiently damning to remove potential sites from serious consideration, or, if the site had already been snapped up by a rival concern, as Cushman apparently had been, as a way of taking some of the sting out of losing.[17]

The city had tried to cope with the growing shortage of electricity by adding a small hydroelectric plant utilizing water from the Volunteer Park reservoir and by building the Lake Union steam plant in 1914, but these were stopgap measures. Seattle's population and industrial bases were expanding, and the City Lighting Department could not supply the quantities of electricity required to continue to compete with the rival private utility, Puget Sound Traction, Light & Power. Worse, World War I created a fuel oil shortage and only the need by war-related industries for electricity allowed the city to obtain the fuel necessary to fire the Lake Union Steam Plant. The Superintendent of Lighting was forced simultaneously to plead for increased fuel oil allocations and to search for a new site for a hydroelectric plant.[18]

The city first began calling for bids on a complete hydroelectric plant in May of 1917 but was forced to delay awarding a contract because no site was available for the city to develop.[19] Two years previously Ross had asked Charles H. Gallant and Willis T. Batcheller, two junior engineers in the Lighting Department, to investigate possible sites for future development. They looked at half a dozen sites in 1915, including Lake Cushman, the Skykomish River at Index, and the Stillagaumish River, and finally concluded that the Skagit River possessed the greatest potential for hydroelectric development. Unfortunately for city ambitions, the Skagit Power Company, an investor-owned firm, had filed on the Skagit in 1908. The United States Department of Agriculture (USDA), which had jurisdiction over the site due to its location in a national forest,[20] issued a permit to Skagit Power after the firm had potential sites surveyed and drew up plans for a massive gravity dam at Diablo Canyon. The company was unable to secure the necessary capital for development and a few years later became part of a Stone and Webster firm, Puget Sound Traction, Light & Power.

The presence of Stone and Webster, a Boston-based engineering and management consulting firm, was foreshadowed in Seattle in 1886 when Sidney Z. Mitchell and F. H. Sparling helped launch the Seattle Electric Company. Over the years Stone and Webster reorganized and merged numerous small firms, including the Seattle Electric Company, into what became Puget Sound Traction, Light & Power in 1912.[21] When the City of Seattle first entered the utility industry, the city did not do so with the overt intention of competing directly with private firms such as Seattle Electric. The city's stated goal was to furnish power for its own street lighting while the private firms would continue to sell power to industry, private residences, and the street car lines. The city soon changed its strategy and opted to become more involved in the electric business, precipitating a war between itself and private power. As Robert Wing has noted in A Hundred Years of Service: The Puget Power Story, the conflict between public and private power "was waged street by street, alley by alley, house by house and customer by customer."[22] Both sides in the battle periodically accused the other of dirty tricks, including planting spies in each other's organizations and invading the personal privacy of the principals involved.[23]

As City Light cast a covetous eye on the Skagit, it exchanged a series of letters with the Forest Service in 1915 in an attempt to determine whether or not "the Company," as Ross generally referred to Stone and Webster, was serious in its intentions regarding the Skagit. At that time, a variety of state and federal agencies exercised jurisdiction over exploitable waters within the United States. The upper Skagit fell under the administrative control of the USDA and the Forest Service after much of the North Cascades region of northern Washington State became a national forest in 1907.

Ross wrote to the District Forester in December of 1915 to inform him the city was dropping its interest in the Skagit in favor of another location, but by the summer of 1917 Ross decided Puget Sound Traction, Light and Power's actions in buying up numerous other hydro sites around the state provided evidence of the company's intention of seeing City Light "bottled at every turn."[24] He believed Puget Sound Traction, Light & Power had no intention of developing the sites they had filed on but were instead interested only in preventing the municipal electrical utility from expanding. Ross began petitioning the Forest Service for permission to develop the Skagit and on August 2 wired the State Hydraulic Engineer that "the City of Seattle by its supt. [sic] of lighting J. D. Ross hereby applies for permit to appropriate the waters of the Skagit River to the extent of fifty thousand cubic feet per second at a point just below the Thundercreek trailbridge. . . ."[25] On August 8 Ross wrote to the District Forester calling his attention to the fact that since "the Puget Sound Traction, Light & Power Company has held the Skagit site for eight or nine years without development and is now purchasing another site, the Skagit site [should] now be thrown open for immediate development."[26]

For the remainder of the year, Ross and other City of Seattle representatives reiterated this argument -- that Puget Sound Traction, Light & Power had relinquished its rights to the Skagit.[27] Finally, on December 25, 1917, the city received what it had been hoping for, permission from the United States Department of Agriculture to apply for a permit for the Skagit. The two major daily newspapers in Seattle reported the news in dramatically different fashions. The coverage in The Seattle Post-Intelligencer, a newspaper which had editorially opposed the municipality entering the electricity business two decades earlier, was restrained in tone, noting accurately that permission to apply for a permit and actually being issued a permit were two different things. In contrast, the Seattle Daily Times exuberantly gave the story a bold headline and front page coverage, hailing it as a "Yuletide gift" to the city.[28] By January 14, 1918, Ross was optimistically predicting that bids for a hydroplant would be opened by March 1 with the contract let before April 1.[29] Although the final preliminary permit would not be issued until later in the year, Seattle's development of the Skagit had begun.

Developing the Skagit

City's Light's first development plans for the Skagit did not include Diablo Dam and Powerhouse. Although Seattle City Light applied initially for an intake at Diablo Canyon, Ross quickly amended the application because he considered the Ruby Creek site, where Ross Dam is now located, to be more important. The rapid overloading of the Cedar Falls plant demonstrated the deficiencies of a hydroelectric plant that lacked a large storage lake, but at Ruby Creek a large reservoir was possible. It was at this point in the river that the upper Skagit drainage widened into a large valley. Ross believed that the Ruby site constituted potentially the largest of the three possible reservoirs on the Skagit in American territory, and estimated it would have a storage capacity of at least 280,000 acre feet if a dam was built that raised the water 250 feet. Other estimates placed the storage capacity of the basin as high as 3.5 million acre feet, so Ross's estimate was a conservative one.[30] Possibly more important to Ross, however, was the competitive edge it would provide over Puget Sound Traction, Light & Power. He emphasized that, "This reservoir will be 14 miles long and will have five or six times the capacity of the Lake Tapps reservoir used for the Stone and Webster plant on White River."[31]

The first plan for development Ross proposed included only one dam and powerhouse connected by a power tunnel almost 10 miles in length. The dam would be located at Ruby Creek near the present day location of Ross Dam and the powerhouse at "about the 16-mile post above Marblemount," near present day Newhalem.[32] The 20' x 20' tunnel would drop one foot per thousand and would be 51,000 feet long, providing a static head of 950 feet.[33]

While no power tunnels of comparable length or size had been built prior to 1918, long wood stave water pipes and flumes, such as the ten-mile-long flume for the Electron plant on the Puyallup River, were common in the mountains of the western states.[34] Many of the early hydro plants in the western states relied on similarly long flumes to channel small volumes of water at a high head into the penstocks to drive impulse wheels [See HAER drawing Newhalem powerhouse].[35] Although the technical difficulties of the proposed tunnel at Ruby Creek were formidable, they were not unprecedented, and such projects as the Catskill Aqueduct in New York state showed the feasibility of conveying water through a large high head pressure tunnel. Engineers on that project had, in 1914, developed a method of making a water-tight junction between a large steel pipe (e.g., a penstock), and the rock tunnel.[36]

In addition, preliminary studies of the Skagit and on-site observations convinced Ross that the Ruby site not only would yield the greatest storage, but also would present the fewest overall engineering difficulties. Reports from consultants such as Henry Landes of the University of Washington supported development of the Ruby site. Landes reported that the bedrock underlying the river below Reflector Bar [near present day Diablo] could have wide variations in it, and that the large rocks and gravel in the stream bed might present difficulties in determining the exact depth to bedrock. The strength of the current at Canyon Diablo would have removed most debris above bedrock, but that same strong current would make handling the stream flow during construction difficult. Despite these reservations, Landes concluded:

> I am convinced that the upper Skagit River offers the safest and most satisfactory dam-sites and storage reservoirs that are to be found in any locality in the northwest. The conditions for the construction of masonry dams of large size are well-nigh ideal, and the opportunities for the storage of water, without the slightest leakage, are unsurpassed.[37]

As planning progressed, it became clear that no matter how promising the Ruby site was, logistical difficulties precluded it from being the first step of the Skagit development. Transportation would be a problem, despite the optimism expressed by consultants such as Michael M. O'Shaughnessy, who noted in 1918 that "from Rockport to Marblemount there is a good wagon road 9.6 miles, and a temporary passable road for 7 miles more, from the end of which transportation up the Canyon is by a well-travelled horseback trail."[38]

By March of 1918 Ross had altered his original plan, and was describing a new development sequence. First, a small hydroelectric plant was to be constructed on Newhalem Creek near where it entered the Skagit River a short distance downstream from the site for what is now the Corge Powerhouse. The power from this facility would be used to help construct the Gorge facility, to be located only 16 miles from Marblemount. The next stage of development would be the construction of Ruby dam to create a large storage reservoir. In the last step a powerhouse would be built downstream from Ruby Dam somewhere in the vicinity of Diablo Canyon.

By 1920 construction work had begun in Newhalem. City Light began building a railroad from Rockport to the site of the Gorge plant, a distance of approximately 26 miles, and had a sawmill operating to supply lumber for the camp. A 3,000 hp hydro-electric plant to supply power for construction was planned for Newhalem Creek.[39] The Newhalem powerhouse, equipped with a double-hung Pelton wheel and a 2000 kva horizontal shaft generator, was completed close to schedule and began supplying power to the construction camp in 1921.[40]

In June 1918 Power reported Ross had submitted a report to the Board of Public Works giving "the initial cost of the Corge development as $4,712,080." The report called for a 25-foot high diversion dam and a flume and tunnel 12,000 feet long.[41] C. F. Uhden, Chief Engineer for the Skagit project, elaborated on the development plan in 1920, saying that:

> It is the intention ultimately to utilize, as nearly as is practical, the entire flow through the total available head. This will be accomplished by means of two plants, one in the vicinity of Stetattle Creek and one in the vicinity of Ladder Creek, the former having a dam just below the junction of Skagit River and Ruby Creek and the latter having a dam just below the outlet of Gorge Creek.
>
> The waters of Thunder Creek will be utilized by means of a

> tunnel connecting it with the Ruby Dam and the water of Stetattle Creek will also be carried in a tunnel terminating at the surge tower above the plant."[42]

Uhden noted that the "ultimate development" of the Gorge Dam would include a dam 240 feet high and two power tunnels each 11,000 feet long.[43]

Various construction delays slowed the work, but in the fall of 1924 Gorge Powerhouse [See Figure 29] began transmitting power to the city of Seattle. Two 30,000 kva Westinghouse generators driven by S. Morgan Smith turbines, each rated at 38,800 hp, were on line. The powerhouse was designed to house three units, but the third generator, rated at 33,000 kva, was not added until 1929. The generators were designed to operate under a 375-foot head, but the low temporary diversion dam at the headworks provided only 270-feet and reduced the actual output of the generators to approximately 20000 kva apiece.[44]

The unique design for Gorge Powerhouse created problems when the plant first went on line. The fact that the water in the tunnel went directly from the power tunnel to the penstocks without passing through a forebay worried the operators. Attempting to synchronize the generators was apparently difficult, with frequent episodes of hunting between the generators, and surging in the penstocks and tunnel resulted. The plant experienced problems with water hammer (a sudden and extremely high pressure in a pipe produced by changing the flow too rapidly) shortly after being started up, and one episode of surging proved so severe the control shafts for the governors broke. The Lighting Department Efficiency Committee held hearings at which it was clear that members of the International Brotherhood of Electrical Workers (IBEW) did not believe the Johnson valves connecting the penstocks to the turbine scroll cases were safe.[45] The pressure used to move the plunger is the pipeline pressure itself and, according to the Larner-Johnson Valve & Engineering Company, fabricators of the valves, this eliminates the need for elaborate headworks.[46] The operators feared that under sudden pressure changes the Johnson valve would slam shut too quickly, exacerbating the water hammer created when the wicket gates for a turbine closed suddenly, and a disaster such as the one that occurred at the Big Creek hydroelectric plant in southern California would result. In that instance a penstock had ruptured and two persons working in the hydroelectric plant had died.[47]

Despite the IBEW's initial uneasiness, the original Johnson valves remained in place until March 1980 and, as the operators became more familiar with the plant and learned to adjust the governors, surging episodes decreased.[48] Although problems such as gravel washing into the power tunnel and damaging the blades on the turbine runner were to plague the Gorge plant until completion of Gorge High Dam in 1961, by 1925 the Gorge facility was on-line and the Lighting Department resumed planning for Ruby Dam.[49]

Designing Diablo

The selection of an appropriate and economical dam design for Ruby was, of course, a crucial consideration. As historian Donald Jackson has noted, dams can be loosely divided into two distinct traditions, the massive and the structural. Massive dams rely on the dead weight of the materials used in construction for stability and are generally referred to as gravity dams, while structural dams resist the hydrostatic pressure of the impounded water through their design features.[50] Structural dams can also be divided into two general types, arch and buttress, and arch dams can be further divided into multiple-arch and single arch, although multiple-arch dams can also be classified as a special type of buttress dam. Single arch dams are generally found in narrow canyons as the dam attains its stability through the arch action transferring hydrostatic pressure to the dam's abutments. While American construction projects in general have been dominated by massive gravity dams, during the early twentieth century a significant number of structural dams were built in the mountain canyons of the western United States.[51] Many of these structural dams, particularly the arch dams, were designed by a consulting firm, the Constant Angle Arch Dam Company, headed by a European-trained engineer, Lars Jorgensen.[52]

Lars Jorgensen was born in Denmark in 1876 and received his engineering education in Germany. He immigrated to the United States at the turn of the century and worked briefly as a draftsman at General Electric in Schenectady, New York. By 1903 Jorgensen had relocated to Los Angeles and an engineering position with Edison Electric. In 1905 he moved to Pacific Gas and Electric in San Francisco, and was there for two years. He joined the engineering consulting firm of F. G. Baum in 1907 and remained there until 1914, when he founded his own firm, the Constant Angle Arch Dam Company. Jorgensen patented the concept of the constant angle arch dam, a type of thin arch dam which was reportedly both stronger and more economical to construct than a thin arch constant radius dam. He based the constant-angle arch dam upon the fact that in a constant radius -- i.e., a simple cylindrical section -- arch dam, there would be only one arch near the top of the dam that was the correct shape for true arch action and stability. The other sections would have central angles which were either too large or too small. A constant-angle arch dam utilizes the principle of drawing correct arches for each contour level and then stacking them to form a dam. If the dam is a tall one, this can result in the top sections overhanging the bottom. To the observer the resulting structure thus resembles a section of a cone or an ellipsoid rather than a section of a cylinder.[53]

Jorgensen designed his first constant-angle arch dam at Salmon Creek, Alaska, in 1914. The Salmon Creek dam was 168 feet high with a crest 640 feet long. By the mid-1920s the Constant Angle Arch Dam Company had designed a number of important dams in the western United States, but the one that apparently landed Jorgensen's firm the Diablo contract was not his biggest nor his most challenging -- it was the dam his firm designed at Lake Cushman for the City of Tacoma that caught the eye of J. D. Ross. Cushman Number One was completed in 1925, and Ross liked the way it looked. A self-trained engineer, Ross tended to be imitative rather than innovative, and often borrowed what he perceived to be worthwhile ideas from other facilities. Corge Dam had originally been envisioned as being just such a large, permanent masonry dam, but the shortage of construction materials following World War I and the depth of the gravel in the river bed mandated a low timber-crib weir instead. While lacking in aesthetics, the Gorge dam worked, although with limited storage capacity. There were disagreements among city officials about what type of dam to build and where to put it, but no one disputed the need for a permanent masonry dam. At the very least, a high dam was necessary to regulate the flow of water for Gorge Powerhouse.[54]

In December Ross wrote to Jorgensen saying, "I like the Cushman Dam and believe your type is the one to use at Diablo." Ross was not a civil engineer and apparently based his decision primarily on aesthetics: he simply liked the appearance of the dam. He invited Jorgensen to accompany "a quiet little party" to the Skagit to look the site over in person and cautioned him to "keep this letter confidential."[55] The complexities of Seattle politics and the continuing competition with Puget Sound Light & Power (by the mid-1920s the company no longer operated streetcar lines and so dropped Traction from its name) encouraged an inclination toward secrecy, especially as at the time Ross wrote, Diablo was just beginning to be discussed again as a dam site. Ross still saw Ruby Dam with its potential for a large reservoir as being the most important dam on the river, but the construction difficulties it presented, including the extension of the railroad from Newhalem to the Ruby site, forced the Lighting Department and Ross to consider alternatives. A dam at Diablo was one of them. Ross argued that building at Diablo before Ruby made good economic and logistical sense. The Forest Service required all timber be removed from the site of any potential reservoir and the planned basin for Ruby Dam was both large and densely forested. It was also almost inaccessible. The narrow and twisting canyon -- at one point at Diablo Canyon the walls were a mere ten feet apart -- precluded river drives for transporting logs and no roads existed. Earlier planning for Ruby Dam assumed a railroad extension from Gorge to Ruby would be built, but by late 1925 Ross changed that plan:

> There is a method by which the necessary time for removing timber can be taken and by which this part of the railway can be dispensed with, by substituting water transportation. The timber can then be sold to better advantage and the $750,000 can be saved and applied on construction. . . . All these difficulties could be overcome and these economies be effected by building Diablo Dam as a means of transporting materials to Ruby Dam by water and by building Diablo power house as a means of furnishing power to be stabilized by the Ruby Dam.[56]

By January 1926 the Seattle Board of Public Works had selected the Diablo site for the next phase of the Skagit Project and the city filed an application with the state for water power rights at Diablo Canyon.[57] In September 1926 the Journal of Electricity reported that "work will start as soon as materials and equipment can be moved to the site" and that construction of a railway extension from Gorge Creek had begun.[58]

Selection of a site and approval of construction funds for the railroad did not put an end to debate over the Skagit project. Seattle city politics were always volatile -- during the 1920s each mayoral election saw the incumbent defeated -- and support for Lighting Department varied with each change of administration. Jorgensen himself recognized the complexities of the Skagit project in doing design work for the city. For example, in 1928 when he wrote to Ross regarding proposed sites for a new Gorge Dam he emphasized "There is one additional reason why complete fundamental data must be in hand in this case before a decision should be made, that is the political aspects of this particular case."[59]

In addition, investor-owned and municipally-owned utilities clashed frequently on a state and national level. In 1922 investor-owned utilities successfully lobbied against proposed state legislation introduced by the representative from Tacoma, Homer T. Bone,[60] which would have allowed municipal utilities to sell electricity outside their city limits. Acrimonious dealings with Puget Sound Light & Power over the years served only to intensify Ross's perception of private power interests as the enemy, and he campaigned vigorously for the Bone bill.[61] Episodes such as Puget Sound Light & Power's 1922 offer to sell its Tacoma line to the city struck Ross as typical underhanded maneuvers by the investor-owned utility.

At the time, the City of Seattle and the City of Tacoma were planning a tie-line to interconnect their municipal electrical plants, and Puget Power Sound & Light's offer would apparently have saved both municipalities time and expense. Ross investigated, however, and determined the line was in such poor shape it would require replacement in the near future. He concluded Puget's president, A. W. Leonard, was attempting to burden the City with a double cost: first, the purchase of the line, and, second the cost of building a new line to replace it. His letter to the City Council was typically blunt:

> If the object. . .follows their characteristic style of shoving on an unsuspecting public something that has depreciated beyond zero, with the hope of getting something out of it, and hampering City Light by worthless service, they are also doing very wrong. . . ."[62]

The Skagit Project with its cost overruns and delays invited criticism to begin with -- like many construction projects, every phase of the Skagit took longer and cost more than had been estimated originally -- and Ross's efforts to promote municipal ownership elsewhere in the state along with his campaign to develop regional networks between the individual municipalities exacerbated the situation. Advocates of private power attempted several times to sell the city Lighting Department, but each attempt failed.[63] In 1925 Ross vehemently opposed a move to amend the city charter to provide a city manager form of government. He argued approval of the amendment would "wreck the city light and power plant."[64] Ross apparently feared the introduction of a city manager-style of government was a ploy both to weaken his own control over the Lighting Department and to make it easier to sell the plant to outside interests. As noted earlier, Ross managed to outlast or outmaneuver Seattle's numerous mayors.

A city manager, however, would not be directly responsible to the voters and thus would be less vulnerable to political pressure. Ross always claimed that he was neither a politician nor an empire-builder, but at the same time he worked hard to ensure defeat of the measure. Having spent over twenty years shaping the Lighting Department, Ross did not intend to relinquish his visions without a fight.[65] Voters rejected the measure at the polls in November, but other distractions quickly arose.

The Davis family, who had homesteaded at Cedar Bar in 1898, refused to sell their land near the site of the proposed Diablo dam to Seattle City Light and condemnation procedures had to be undertaken. A jury in Whatcom County heard the case and in April 1927 awarded the Davises $12,380 in damages.[66] The Davis litigation was a minor nuisance, however, compared to a mysterious telegram questioning the safety of the proposed Diablo dam.

The Shuffleton Telegram and Arch Dam Safety

In addition to applying to the state for water rights, the location of Diablo in a national forest meant Seattle City Light had to obtain a federal permit. Shortly after the Constant Angle Arch Dam Company had been awarded the design contract for the Diablo Dam in the spring of 1927, Lars Jorgensen was in the San Francisco office of the Federal Power Commission's Local Engineer trying to hurry along this permit process. Several months previously Jorgensen's firm had submitted the designs of the principal structures proposed for the Diablo site required for the exhibits mandated under Regulation 4 Section 12 of the Federal Water Power Act several months before, and had also complied with the FPC engineers' requests for design changes and clarifications, but the FPC still had not issued the necessary permits. The structure of the FPC, with its authority shared by three cabinet departments -- War, Interior, and Agriculture, lent itself to delays,[67] but Jorgensen believed the FPC was being even slower than usual. On June 7, 1927, Jorgensen wrote to W. C. Morse, City Engineer for Seattle, that:

> We have been somewhat surprised at the severity with which the Local Engineer for the Federal Power Commission have gone into the minutest details of the Canyon Diablo Dam Design and the time spent on the check.
>
> Today I found the enclosed telegram on his desk and got it copied without him knowing it. I thought it would interest you, as it fully explains his painstaking efforts.[68]

The telegram Jorgensen referred to, signed by a "D. A. Shuffleton", declared the dam design to be unsafe in no uncertain terms:

> On behalf of myself and associates I hereby protest and urge that you deny the issuance of the Diablo Dam permit now before you for consideration. Constant Angle Arch Dam Company Jorgensen and Brehme appeared before our council men and guaranteed the approval of Federal Power Commission no approval no contract giving public

> impression that federal officials were interested in this company. Elaborate concrete miniature model of Diable [sic] canyon topography with Jorgensen dam in place all constructed to scale failed as you can confirm by inquiry. Six thousand people living below this frail eggshell affair three hundred eighty feet in height will protest its construction by petition to Governor Hartley and U. S. Senators if a permit is issued without public hearings at Mount Vernon and Sedrowooly [sic] and other cities interested.[69]

Jorgensen's attorneys, the City of Seattle, the United States postal inspector, and the Federal Trade Commission all attempted to track down D. A. Shuffleton to no avail. The reason there was such a keen interest in ascertaining the identity and whereabouts of D. A. Shuffleton was that Samuel Shuffleton had, for many years, served as Stone and Webster's chief engineer in the Pacific Northwest. Who D. A. Shuffleton was remained a mystery even though he apparently succeeded in recruiting allies: a Mr. Davis, perhaps the same Davis who refused to sell the family homestead on the Skagit, living below the dam site also wrote to the FPC expressing his concerns in terms which were reportedly almost identical with Shuffleton's phrasing.[70]

Jorgensen, who called the telegram incident "a nice piece of politics coming from Stone & Webster," was not alone in suspecting attempted sabotage by Puget Sound Power & Light.[71] Indeed, the Shuffleton telegram fit into what many people believed to be the larger pattern of harassment and conniving on the part of investor-owned utilities. For example, Homer T. Bone,[72] in correspondence with Ross spoke of "the battle" with Puget Sound Power & Light Company. In response to an article in the Post-Intelligencer, which quoted A. W. Leonard, president of Puget Sound Power & Light, as intending to "smash and take over the City Light Department," Bone promised to "ladle out to that gentleman and his outfit enough concentrated hell to furnish him food for reflection for the balance of his life."[73]

The Shuffleton telegram also played upon the fears of the American public regarding dam safety. The early years of the twentieth century were notable not only for the large number of dams constructed, but also for a number which failed.[74] While no arch dams such as the one planned for Diablo were among the failures, many people continued to view arch dams with suspicion, and civil engineers vigorously debated the safety of such seemingly fragile structures in professional journals. As a prominent early twentieth century civil engineer and author of a classic book on dam design, Edward Wegmann, noted, prior to the twentieth century such dams deriving their stability from horizontal arch action were extremely rare, and conservative engineers distrusted them. For many years, the Zola dam, built in France in 1843, was the only one of its type,[75] but the development of the American West, with its mountainous regions scored with narrow canyons, spurred interest in arch dam design by American civil engineers. In 1884 the Bear Valley Dam became the first American thin arch dam. Wegmann described it as "surpass[ing] in boldness all other dams built"[76] as it owed its stability solely to the arch action of the wall of the dam. The engineer who designed it, F. E. Brown, selected the design as being the most economical for the remote site in the San Bernadino mountains of southern California. All cement, tools, and supplies had to be hauled approximately seventy miles over rough mountain roads. Although the dam evidenced no structural failings, according to Wegmann its daring design worried the irrigation company which owned it, and in 1910 the firm replaced it with a multiple-arch dam.[77]

The early twentieth century witnessed a flurry of activity both in dam building and in innovative dam design.[78] Increasing knowledge about the properties of an old material, concrete, allowed it to be employed in new ways. The compressive strength of concrete could be calculated and a scientific approach to dam design utilized. While early examples of arch dams used a simple cylinder formula to determine dam thickness, theorists such as William Cain, a mathematics professor at the University of North Carolina, began arguing the inadequacies of the cylinder formula in a series of papers published in Transactions of the American Society of Civil Engineers. Cain developed a formula for determining the principal normal stresses at any point in a dam and the planes in which they act, and then, recognizing that the calculations involved could be lengthy and complex, developed tables to simplify the use of those formulae.[79]

At the same time, while engineers acknowledged that the cylinder theory was flawed (because an arch dam is never a complete cylinder and so the stresses and dimensions calculated are only approximately correct), they continued to use it successfully. In 1919, for example, A. F. Parker reported on an arch dam he designed for East Canyon Creek in Utah utilizing the cylinder formula. At the same time, Parker argued for empirical testing of arch dam design because he believed that as things currently stood no way existed for determining actual safety factors. Parker sounded both defensive and exasperated when he wrote:

> From the numerous articles describing arch dams, the many discussions on their design, and the frequency with which lists of arches actually built appear in such articles, one gains the impressions that a general doubt exists as to the safety of structures of such slight appearance. However, the fact that so many arch dams -- many of strikingly light section and frequently subjected to trying conditions -- have been built without a single instance of failure occurring, which cannot be said of any other type, is strong proof of good qualities and safety. The test of actual use shows that arches under pressure are the safest form that can be built.[80]

Arch dams had, in fact, a superior safety record when compared to other types. In 1921 Fred A. Noetzli argued that gravity dams had a much lower safety factor regarding overturning than had been previously supposed, and that arch dams were both safer and more economical. Noetzli, like Parker and other proponents of arch dams, concluded that scientific testing was the only way to resolve the debate over the safety of arch dam design.[81]

By 1922 the debate over the safety of arch dams generated enough pressure within the engineering and construction communities that the Engineering Foundation[82] undertook a long term study of arch and multiple arch dams. In addition to studying dams already in use, in 1926 the Foundation used contributions from seventy-five industry and government sponsors to construct a test facility with an experimental arch dam on Stevenson Creek in central California. The dam stood sixty feet high, taller than many arch dams actually in commercial usage at the time, and measured 140 feet along its crest. The United States Bureau of Standards recognized the broad implications of the research and assigned W. A. Slater, an Engineer-Physicist, as chief experimenter for the research project. In late summer and early fall of 1926 the reservoir was filled and deflections of the dam measured at various water levels. In addition to the stresses experimenters deliberately imposed upon the dam, in November 1926 an unexpected flood occurred when debris choked the undersluice. debris. Water filled the reservoir, overtopped the crest of the dam by a depth of three feet, and demolished test equipment and scaffolding on the downstream side of the dam. The dam itself suffered no apparent damage from the flood.

When the investigating committee printed its preliminary report in the 1928 Proceedings of the American Society of Civil Engineers the members tentatively concluded that the great strength of thin, unreinforced concrete arch dams had been effectively demonstrated. Rather than agreeing with past critics who felt arches of dams were becoming "unnecessarily thin,"[83] the committee concluded dams could be even thinner and greater economies realized, it being the goal of every engineer to find not only the safest but the most cost-effective structure possible.[84]

Even this empirical testing could not placate all doubters, including engineers involved in preparations for the Diablo project.[85] George Moore of the Seattle City Engineering Department was not alone in "being an avowed atheist concerning the value of the Cain formula, the cantilever theory, and the hypothesis that arch dams act as if they were made up of horizontal slices one foot thick. . . ."[86] Arch dams, however, offered a significant savings over gravity dams because in most settings arch dams used a much smaller volume of materials -- see HAER Drawing Gorge High Dam for a comparison of the profiles of the gravity section and the thin arch section for an illustration of the difference in volume of construction materials -- and Bernard J. Jakobsen, an engineer who had worked with Jorgensen, projected additional theoretical savings of 23 percent if a constant angle design was utilized instead of a constant radius.[87] When faced with the combination of an almost inaccessible site, suitable topographical features (i.e., a narrow granite canyon ideally suited for arch dam construction), and rising costs of materials, even the most conservative of engineers could change their minds. Jorgensen himself was an expert at arguing for the economy of his constant-angle arch dam and had been involved in at least one project where construction actually began before the design change was made: the Lake Spaulding Dam began as a gravity dam but was changed to a constant angle after a height of 60 feet had been achieved and money became tighter.[88]

Although civil engineers in the City Engineer's office such as Moore watched the test proceedings at Stevenson Creek with great interest, whether the Lighting Department and Ross himself were aware of these issues when Jorgensen was asked to design Diablo Dam is unknown. Certainly in his correspondence Ross treated the Shuffleton telegram as an annoyance, a dirty trick perpetrated by private power interests, rather than as a part of a larger debate within the civil engineering community.[89] The failure of the mysterious Shuffleton to come forward with the proof the telegram claimed combined with the FPC's Local Engineer's careful scrutiny of Jorgensen's plans apparently allowed O. C. Merrill, the FPC executive secretary, to state with confidence in correspondence to Jorgensen that the commission did not consider the design unsound.[90] On October 15, 1927, the FPC approved the constant-angle arch dam design for Diablo. Shortly after, the city completed the railway extension from Gorge to Reflector Bar and awarded the construction contract for the dam to Winston Brothers of Minneapolis.[91]

Distractions at Hanging Rock

Construction of the Skagit Hydroelectric Project took place over a period of fifty years, and the start of one phase did not always mean the end of a previous one. While design work for the Diablo Dam progressed, the Lighting Department and the City Engineer continued to grapple with the ongoing problems at Gorge. Although the city was concentrating most of its attention on the Diablo site, a proliferation of problems at Gorge became too serious to ignore. Gravel being swept into the intake and low water levels interfered with the efficient operation of the plant.[92] In June 1927 Ross suggested construction of "a re-enforced concrete dam of the Ambursen type"[93] just below the timber crib dam at Hanging Rock. Such a dam would raise the pool to elevation 790 and increase the storage from twenty acre feet to 200.[94] It would also allow the installation of a third unit at the Gorge plant.[95] The City Council concurred with Ross that a new Gorge Dam was needed in addition to Diablo Dam, and the council approved funding for preliminary design work in August 1927.[96] By December 1927 the council had authorized a bond issue to cover the cost of constructing an Ambursen-type dam at Hanging Rock, but the City Engineer, Chester Morse, threw a spanner in the works. Morse had reviewed the proposed contract with the Ambursen Dam Company and considered "the price entirely too high."[97] When the Lighting Department's annual report for 1927 came out early in 1928 it agreed with Morse and condemned the Hanging Rock plan as "a financial and engineering blunder."[98] This put the City Engineering and Lighting Departments, who in previous years had clashed over Ross' efforts to gain a charter amendment which would allow Seattle Light to organize its own construction work, in the unusual position of agreeing with each other while disagreeing with a majority of the city council.[99] The Hanging Rock scheme was dropped in 1929, with the city deciding to raise the existing crib dam two feet in height at an estimated cost of $25,000, instead of investing $3,000,000 in a new dam.[100]

Construction at Diablo

On January 1, 1928, Winston Brothers began excavations for Diablo Dam and on July 12 the first concrete was poured. The city completed its standard-gage railway extension from Gorge to Reflector Bar and in March finished constructing an incline to transfer railway cars to the higher elevation at the top of the dam. Because the city planned future developments farther up the Skagit, the incline was designed as a permanent feature rather than simply as a convenience for the contractors on the Diablo project. Engineering News-Record described it as:

> . . .a funicular railway, the counterweight passing under the transfer platform at the midpoint. The incline length is 563 ft. and the difference in level between the two extreme positions of the transfer platform is 313 feet. . . The incline proper consists of three standard-gage tracks, of which the one in the center is used by the counterweight and the two others, whose center lines are 42 ft. apart, support the moving platform, 60 ft. in length, built up of structural steel. This platform is supported on four four-wheel standard gage trucks, the wheels having a tread diameter of 24 in. Standard equipment was used as far as possible in all trucks and track work so as to simplify construction maintenance and operation.[101]

The incline allowed fully loaded freight cars to be transported up a 68 percent grade without having to rehandle materials or transfer them into special cars.[102]

Construction of the dam involved considerable ingenuity and the development of innovative approaches for both the preliminary excavation work and actual erection. Simply preparing the site proved a challenge. The canyon walls as well as the floor had to be stripped of all rock which was not solid bedrock. The excavation began before the stream bed was dewatered to allow the spring flood waters to aid in carrying away debris. After the river was diverted via a cofferdam and tunnel excavated through the south bank of the canyon, power shovels attempted to clear the stream bed itself, but the firmly embedded boulders proved difficult to move. Manganese-alloy dipper teeth reportedly seldom lasted more than one shift.

After the site was cleared Winston Brothers devised an innovative series of belt conveyors and hoist towers to move the concrete from the mixing plant to the pour sites on the dam (See historic photos in Field Notes). An elephant trunk at the end of the conveyer allowed smooth continuous delivery over the entire surface to be concreted, and a 5-foot lift was normally completed in five continuous 1-foot layers. The puddlers distributed gravel pockets with shovels and forced down any rocks showing on the surface of the pour, but the concrete required little other handling by the laborers. The conveyor system was designed to move 80 cubic yards of concrete per hour under ideal conditions, but the average day's run in June 1929 for a three shift day was only 1143 cubic yards, or not quite 48 cubic yards per hour.[103]

However, not even the ingenuity of the Winston Brothers could compensate for the delays created by bad luck. As predicted ten years earlier by Landes, the strong currents through Diablo canyon caused problems. Flooding occurred several times and washed out a portion of the cofferdam at least once in 1928. The hoist gear of the incline broke and consequently was out of service for a month in 1929. The February 28, 1929, issue of Western Construction News reported that construction of the dam had advanced to the point where concrete in the channel section was above danger from floods, and it was estimated the project would be completed by November 15, 1929.[104] By December 1929, however, the contractors were forced to ask the Seattle City Council for a year's extension, even though over 243,000 cubic yards of concrete had been placed. A revised construction schedule estimated it would take another twelve months to complete the dam.[105]

Eight months later, on August 27, 1930, the City of Seattle and Winston Brothers held a dedication ceremony. Work on the 389-foot high, 1,180-foot long dam was officially complete.[106] The dam had taken almost three years to build, but the city finally had something to brag about: Not only did it create the storage needed for Gorge to operate efficiently, in 1930 Diablo Dam was the highest thin arch dam in the world.[107] Although Lars Jorgensen chose to downplay the achievement when he modestly described it as a "typical example of a high constant-angle arch dam spanning a rather large gap," Diablo was, and still is, a remarkable feat of engineering.[108] The bare statistics which summarize its construction, e.g., 1758 carloads of cement, 630,000 tons of gravel aggregate, 350,000 cubic yards of concrete, do not adequately convey the aesthetic aspects of the dam.[109] Combining beauty with utility, the roadway above the crest of the dam is carried on arches, and includes ornamental lighting standards on the parapets.

As Diablo Dam neared completion, the Lighting Department and the City Engineer worked on designs for the powerhouse. The generating units had already been ordered, as had much of the other equipment for the facility, when a combination of events slowed construction. W. D. Barkhuff, the City Engineer the Lighting Department had been working with, died suddenly and Reginald H. Thomson was appointed to the position. Thomson immediately began to scrutinize the existing plans for Diablo and found numerous flaws in the proposed design for the powerhouse. Ross envisioned a plant with a single floor plan in which the generators were to rest on pedestals similar to the ones at Tacoma's Cushman Number Two plant, which Ross termed "the most modern we have seen." He argued that "the majestic appearance of the single floor station as against that buried in two floors is itself enough to justify this plant, and be a credit throughout the years to its builders." He suggested to Thomson that if cost were a factor, "all the tile and frills could well be cut out and save $150,000 on these things. . . ."[110]

Thomson's response to Ross's suggestions was to methodically demolish the ideas as being unsound, impractical, and expensive. He believed the pedestal arrangement in particular would be unsafe and emphasized in correspondence with the Lighting Department that no powerhouse utilizing a pedestal arrangement employed generators as large as the equipment planned for Diablo. In a lengthy memo to Ross he expressed his professional belief that "the stiffening action of a floor at this point. . .is absolutely essential for units as large as those for the Diablo Plant." Thomson, reflecting the overall increasing awareness among civil engineers in the 1920s of the importance of external aesthetics, then noted, "No attention whatever has been paid to the architectural features of the building. The impression gained by the visiting public depends to a marked degree upon this feature alone."[111]

The debate over the powerhouse plans involved more than a simple disagreement over building design. The powerhouse had become part of a larger political debate raging within the city of Seattle over a proposed charter amendment to allow the Lighting Department to do its own construction planning. Ross had been striving for greater autonomy for the Lighting Department for many years; the City Engineer adamantly opposed the move. If the Seattle Lighting Department did its own civil engineering, the City Engineer's office would cease to be involved in much of Seattle's major construction projects. Thomson accused Ross of incompetence; Ross in turn accused Thomson of being a tool of Stone and Webster. This political tug of war over the plans for the Diablo powerhouse was resolved on March 10, 1931, when the voters gave "authority for planning and development of the power system to the same officer and organization charged with its successful operation."[112]

Unfortunately, as the political turmoil died down, the supply of money dried up. It had always been the custom of the Lighting Department to issue bonds only as money was needed, and in the 1920s they had not wanted for purchasers. The early 1930s, however, were a different story. The city tried several times to market bonds in 1932 and 1933, but it was not until 1934 that it succeeded in interesting a group of New York bankers in taking on an issue of $4,956,000 in City Light bonds to finance construction at Diablo powerhouse.[113]

Federal funding was also lacking for City Light projects. As a firm believer in public power, J. D. Ross had advocated increased government involvement for many years. Beginning in the 1920s he had pushed for the creation of a network, or power pool, in the Northwest, and viewed the city's tie-line with Tacoma as a first step toward this wider network.[114] It is one of the ironies of the Skagit project that its development was temporarily delayed after the federal government committed itself to building two major dams on the Columbia River, Crand Coulee and Bonneville. The city dedicated Diablo Dam on August 27, 1930, but gaining funding for the Diablo powerhouse proved to be a struggle. Clearly, Ross had not anticipated that the federal government's entry into the hydroelectricity business in Washington would lead to years of frustration for Seattle's Skagit projects.

City Light's efforts to gain federal money began with an attempt to obtain full funding from the Reconstruction Finance Corporation. The city's August 1932 application for a $7,500,000 loan was refused, and instead the RFC conditionally offered to lend the city $1,625,000, through the purchase of city bonds, if the city would clear up any outstanding warrants from its construction fund. In December, when the RFC made this offer, outstanding warrants totalled $1,854,000.[115] A change in presidential administrations and the birth of the New Deal in 1933 did not help. The great federal public works projects on the Columbia made the government reluctant to fund any additional projects in the state of Washington. As Secretary of the Interior Harold Ickes saw it, Washington had "already received a generous share" of Public Works Administration monies.[116]

Ickes plainly was not moved by the fact the powerhouse foundations were complete, as were the power tunnel, surge tank, and penstocks. They all had been constructed as part of the Diablo Dam project. The generators and other equipment had been received and were stored in heated buildings at Reflector Bar. To complete the project, contractors were asked to bid on a powerhouse superstructure to be erected on existing foundations, a tailrace, assembly and erection of the previously purchased powerhouse machinery, the furnishing and wiring of switchboards, and the construction of a 220-kv., double circuit steel tower transmission line to run from Diablo to Gorge.

The equipment the Lighting Department had in storage included the highest rated generators built up to that time.[117] Historian Richard Hirsh has noted that the managerial culture of American electric utilities, both public and private, in the 1920s encouraged technological one-upmanship and Seattle City Light and J. D. Ross were no exception.[118] The original design for Diablo had called for generators only slightly larger than those at Gorge; in 1928 the proposed size had increased to 45,000 kva, by the time the order was placed the required rating had grown to 60,000 kva, and when the Westinghouse generators arrived they were rated at 66,700 kva.

The increased size of the generators and turbines entailed the creation of a proportionately larger overhead crane to move the various parts of the units. In September 1932 a power bridge crane reported to be largest ever built was shipped to Reflector Bar by the Harnischfeger Corporation. The 300-ton two-trolley travelling crane weighed 392,800 pounds and was provided with seven motors. The crane had two crabs, each with a main hoist capacity of 150 tons, and an auxiliary hoist of 25 tons. The maximum lift was taken by the two main hoists and a lifting beam.[119]

The successful sale of the bond issue in 1934 meant the equipment which had been stored for four years would finally be put to work.[120] As usual in Seattle, politics played a role as the mayor vetoed the bond issue, but the city council promptly overrode his veto.[121] In July 1934 the Lighting Department began constructing a transmission line between the Diablo and Gorge powerplants. Though the original construction contractor forfeited the job after only two weeks, a new contract was soon awarded to Rumsey and Company, and by July 1935 Ross was preparing to install the powerhouse equipment.[122]

In March 1929 the City Lighting Department projected a completion date of September 1930, but six years passed before the powerhouse was finished.[123] City Light officially dedicated the powerhouse on September 23, 1936, when

"President Roosevelt pressed a button at his home at Hyde Park that transmitted an electrical impulse across the continent to start the first Diablo generator."[124] Putting Diablo on line involved fewer problems than had been the case with Gorge twelve years earlier. The gravity oil system failed to work as designed and had to be revamped, but no dramatic instances of water hammer or other malfunctions occurred. The Diablo powerhouse epitomized the mature technology of hydroelectricity in the 1930s, and the smooth operation of the plant was interrupted only by such external events as rock slides and medical emergencies in the construction camp.[125] By the time the plant was fully operational, the focus of the Lighting Department had shifted. When preliminary excavations for Ruby Dam began in 1937 the ten year struggle to finish the second step of the Skagit development ended and the push for the third step commenced.

The Skagit Hydroelectric Project has been a popular destination for tourists since the 1920s and visitors to the project can tour Diablo Powerhouse, but the attention continues to be on what Ross termed the ultimate development, the biggest dam on the river, Ruby, or as it is now known, Ross Dam. City Light began offering package tours in 1928 of the Skagit development, but even before Diablo Powerhouse was finished the tours were going upstream to admire the site for Ruby Dam.[126] The tours were discontinued during World War II but revived in the 1950s. During the summer months approximately 200 people a day ride the incline lift up the hillside, walk to Diablo Dam, and then board a boat to travel up Diablo Lake to Ross Powerhouse. Only a handful are curious enough to ask to tour Diablo Powerhouse, too, and so miss seeing what is probably the only powerhouse in the country with a goldfish pool in the visitor's lobby. Although Ross had suggested to Thomson one method of saving money was to eliminate the frills,[127] when the time came he spared no expense. The terrazzo floors, the art deco anodized aluminum water fountain, the tiled goldfish pool, and the aluminum caps for the wrought iron railings all bear witness to a time when society still believed that hydroelectricity would allow the dawning of what Lewis Mumford termed "a neotechnic age,"[128] an age that would dispense with the soot and dirt of a coal-fired industrial base and banish forever the grime of traditional factory towns. Like Mumford, J. D. Ross believed in the transcendent possibilities of technology and, in the end, Diablo Powerhouse reflected that belief.

City Light After Diablo

Seattle City Light had planned the Ruby Dam development since it first filed on the Skagit in 1917, and continued to plan toward the ultimate development while work progressed on Diablo. Completion of each power plant -- first Newhalem, then Gorge, and finally Diablo -- to Ross meant the realization of his dream, i.e., the construction of Ruby Dam, moved one step closer. He appears to have never considered the possibility Ruby would not be built. In 1929, for example, Ross persuaded the City Council authorized the purchase of the Whitworth Ranch in British Columbia in anticipation of the flooding that would occur on the Canadian side of the border after the Ruby Creek Dam was completed.[129] In 1931 Ross spent three days visiting the Boulder

Dam site on the Colorado River and discussing dam designs with engineers working on that project, and the city's applications for federal financing in 1932 and 1933 included requests for funding for Ruby Dam, with the major differences in the applications being the amounts requested. In 1932 the total loan requested was a relatively modest $7.5 million, primarily for the completion of the Diablo plant; in 1933 Ross asked for $25.8 million, 80 percent of which he earmarked for the Ruby project despite the fact the Diablo Powerhouse was still far from done.[130] Both the Reconstruction Finance Corporation and the Public Works Administration rejected the applications for financing, and it was not until 1937 that City Light was able to actually begin work at the Ruby Dam site.

In May 1937 Power Plant Engineering reported that Ruby Dam would be a massive straight gravity 635 feet high, which would have made it second only to Hoover Dam in height.[131] The high costs of construction at a site accessible only by water mandated a more economical plan, however, and in July 1937 when the Seattle Board of Public Works awarded a contract for the construction of the first stage of Ruby Dam, the contract called for a concrete arch dam 150 feet in height. The scheduled completion of work on this first stage was set for June 1939. The calculations Lars Jorgensen had provided for the Lighting Department showing that for almost the same volume of concrete an arch dam one hundred feet higher and with a reservoir three times as large as that of a straight gravity dam could be constructed had served their purpose.[132] However, the site's inaccessibility combined with the well-publicized difficulties Winston Brothers had encountered during the construction of Diablo may have discouraged potential contractors as the Board of Public Works received only one bid.[133]

Unlike previous city projects on the Skagit, Ruby Dam qualified for federal funding. Citizens had been requesting a high dam for many years as severe flooding on the lower Skagit periodically devastated farms and communities in the delta, and Ruby's large storage potential meant it could help with flood control. The planned reservoir would cover 20,000 acres and have the capacity to hold the equivalent of 600 days' flow of the river. Because engineers incorporated a large drawdown for flood control into the plans for Ruby Dam, this meant the effective head for the powerhouse to be built later would vary by as much as 200 feet seasonally. Plans for the dam called for construction to proceed in three steps: the first step would bring the dam to an elevation 1300 feet above sea level, the second step to elevation 1515, and the final step to 1728 feet above sea level. When completed, the dam would be 655 feet tall overall.[134] City Light completed the first step of construction in 1940, and the second stage, to a structural height of 540 feet in 1949. Engineers specified that the face of the dam be stepped and keyed (see HAER Photo WA-24-108) for bonding the aggregate when the third and final step was added at a future date.[135] That third and final stage would be added when the power demands of the city warranted it. When the time came, however, thirty years later, the controversy over increasing the size of the reservoir -- it would have inundated approximately 8300 acres of wilderness as well as extending much further into British Columbia than previously -- led to City Light exploring alternative sources of power. Instead of raising the dam, Seattle agreed to purchase power from British Columbia and so, as it stands now, Ross -- City Light dedicated the dam to J. D. Ross after his death in 1939 -- is an unfinished dam, and will probably remain one.[136]

Other construction on the Skagit in the past sixty years included construction of the second Gorge Dam, a concrete diversion dam, in the 1940s. The combination of this dam and the completion of the second stage of Ross Dam enabling greater regulation of water flow in the Skagit allowed City Light to add a fourth generator to the Gorge Powerhouse. This addition to Gorge Powerhouse was completed in 1951 as construction of Ross Powerhouse began. Work on Ross Powerhouse ended in 1957 with the installation of the final and fourth generator, and work on Gorge High Dam resumed.

A high masonry dam had been planned for the Gorge site for many years. City Light engineers explored various schemes to build one, but were defeated by foundation problems with the site. The river bed in the area of where Gorge Creek entered the Skagit was characterized by layers of alluvial material up to 180 feet deep. Previous attempts at building a high dam were given up when efforts to dewater the channel to allow excavations to bedrock failed. Water percolated under cofferdams through rocks and gravel. Pressure grouting with concrete and with rubber-like materials did not work. Finally, a technique utilizing super-chilled brine was developed and engineers literally froze the river -- or at least that portion of the river's flow which was percolating through the river bed. The freeze curtain succeeded and Seattle City Light dedicated Gorge High Dam in 1961.[137]

Notes

1.Henry J. Pierce, Looking Squarely at the Water Problem (Seattle, WA: 1915, Henry J. Pierce).

2.Forest Service, United States Department of Agriculture, The Skagit: A Study of the Skagit, Cascade, Sauk and Suiattle Rivers in Washington State for Possible Inclusion in the National Wild and Scenic Rivers System, 13-14.

3.Margaret Willis, ed., Chechacos All: The Pioneering of Skagit, Skagit County Historical Society, and Will E. Wiley, "Gold Districts of the Northwest," manuscript submitted June 1, 1915, in the Enoch A. Bryan Historical Prize Contest.

4.Glee Davis, Upper Skagit Homesteader 1893, North Cascades National Park 1970.

5.In 1915 a crew led by Glee Davis built the nation's first lookout station 6000 feet above sea level on Sourdough Mountain. It was reached by a switchback trail with a grade of 1000 feet per mile.

6. Will D. Jenkins, Last Frontier in the North Cascades: Tales of the Wild Upper Skagit, Skagit County Historical Society, Mt. Vernon, WA: 1984, pp. 117-118.

7.Jenkins, pp. 30-38 and 41-42, and Davis, p. 8.

8. According to Glee Davis, miners on both Thunder and Ruby Creeks at the turn of the century used Pelton wheels to generate electricity at mining sites.

9. For additional information regarding Mitchell, Sparling, and the history of investor-owned utilities see Sidney A. Mitchell, S. Z. Mitchell and the Electrical Industry (New York: Farrar, Strauss and Cudahy, 1960) or Robert C. Wing, A Century of Service: The Puget Power Story, Bellevue, WA: Puget Sound Power & Light Company, 1987.

10. Wing.

11.Floyd David Robbins, Hydroelectric Power in the Pacific Northwest 1949, a thesis submitted for the degree of Electrical Engineer, University of Washington, 1949.

12. Seattle Lighting Department Annual Report 1930, 8; Seattle Lighting Department Annual Report 1952, 4-5; and Robbins. It was Tacoma, rather than Seattle, that became the first municipality on the West Coast to generate its own electric power when citizens voted to purchase the privately owned Tacoma Light & Power Company in 1893.

13. See letters from J. D. Ross to Franklin D. Roosevelt, Official File 2882: Bonneville Power Administration 1933-36, Franklin D. Roosevelt Library, Hyde Park, New York.

14. For more on J. D. Ross see, for example, Wesley Arden Dick, Visions of Abundance: The Public Power Crusade in the Pacific Northwest in the Era of J. D. Ross and the New Deal, Ph.D. dissertation in history, University of Washington 1973; or Carl Dreher, "J. D. Ross, Public Power Magnate," Harper's Magazine March 1940:47-60.

15. See "Can Make Basin Hold Water but Cost is Unknown," Seattle Daily Times April 22, 1917, p.5+, and Michael M. O'Shaughnessy, Report of M. M. O'Shaughnessy, Civil Engineer, on Power Needs of the City of Seattle 1918, University of Washington Libraries.

16.David A. Harvey and Kent Shoemaker, Cedar Falls Hydroelectric Works HAER WA-15, 1986, pp. 7-9, and "Court Holds City Responsible for Reservoir Failure," Engineering News-Record July 12, 1928:63.

17. See Willis T. Batcheller and Charles H. Gallant, Power Situation in the Puget Sound District, 1918: p. 72., and Letter from J. D. Ross to Gene Evans, August 9, 1918, Folder 10-3 in Seattle Lighting Department Records, Accession 33-1 (hereafter SLD 33-1), University of Washington Libraries.

18. See Letters to W. R. Brown, October 3, 1916, Folder 8-12, George H. Cecil, September 5, 1917, Folder 8-26, and Hugh Caldwell, September 26, 1917, Folder 8-26, SLD 33-1.

19."To pick bids for city light plant," Seattle Daily Times May 19, 1917, p. 4.

20. The Federal Power Commission was created as part of the Federal Water Power Act of 1920. Prior to the birth of the FPC inland waters in the United States could fall under either state or federal jurisdiction, depending upon factors such as the presence of a federal reserve or the navigability of the waters, and a utility company wishing to exploit those waters would apply for permission accordingly.

21. For a more complete history of Puget Sound Traction, Light and Power see Wing.

22. Wing, p. 85.

23. Ross, for example, claimed at one point to have found a recording device hidden in the fireplace in his home. See Dick, pp. 250-259.

24. Batcheller, p. 77. Letter to District Forester, Folder 8-25, SLD 33-1.

25.Telegram to State Hydraulic Engineer, Olympia, Washington, August 2, 1917. Folder 8-25, SLD 33-1.

26.Letter to United States Department of Agriculture, Folder 8-25, SLD 33-1.

27.See Letters in Folder 8-26, SLD 33-1.

28.See "Seattle given power site as Yuletide gift," The Seattle Daily Times, December 25, 1917, p. 1+, and "Good faith must be shown to get power site," The Seattle Post-Intelligencer, December 27, 1917, p. 8.

29. Form letter to potential bidders on hydro-electric plant construction, January 22, 1918, Folder 9-6, SLD 33-1.

30. See, for example, C. Edward Magnusson, "Hydroelectric power in Washington," The Military Engineer XIX.108(1927):458-66; or "Seattle plans further work on Skagit River project," Electrical West March 1927:1.

31.Letter to Honorable Ole Hanson, Mayor, City of Seattle, March 19, 1918, Folder 9-20, SLD 33-1.

32.Letter to George H. Cecil, District Forester, January 16, 1918, Folder 9-5, SLD 33-1.

33.Letter to George H. Cecil.

34.Thomas Hughes, Networks of Power, Baltimore, MD: Johns Hopkins Press, 1983, p. 272; and Barry Lombard, Electron Hydroelectric Project HAER WA-12.

35.Terry S. Reynolds, Battle Creek Hydroelectric System HAER CA-2.

36.Arthur W. Tidd, "Making a Water-Tight Junction of a Large Steel Pipe and a Rock Tunnel under a High Head," Engineering News 72.13(1914), pp. 615-620.

37.Letter to A. H. Dimock, City Engineer, August 12, 1918, from Henry Landes. Folder 10-8, SLD 33-1. See also "Report of Henry Landes on Geology of Skagit River," Willis T. Batcheller Papers, Box 15, Accession 195, 2497, 2497-2, University of Washington Libraries.

38.O'Shaughnessy.

39.C. F. Uhden, "Seattle building large hydro-electric development," Engineering News-Record 85:994-96, p.995.

40. Seattle Lighting Department Annual Report 1954.

41."Skagit River Development," Power, June 11, 1918: 853.

42. Uhden, p. 995.

43. Uhden, p. 995.

44. J. D. Ross, "Skagit River Development of the City of Seattle," Journal of Electricity 55(August 1, 1925):81-3.

45. The valves in question were Johnson valves consisting of a circular body surrounding an internal cylinder closed at one end and connected to the body by radial ribs in which a pointed plunger or needle operated by making contact with a seat in the neck of the body to close the valve.

46.The water flow through the penstocks to the turbines in a hydroelectric facility is controlled at two points: at the dam by a headgate at the intake of the power tunnel and by a valve connecting the end of the penstock to the turbine casing. Larner-Johnson was apparently advocating elimination of headgates, an unwanted innovation as power tunnels must be periodically dewatered for inspection.

47. See, for example, "Penstock bursts during try-out of high-head turbine plant," Engineering News-Record October 20, 1921:640-41; Reply to Testimony at Hearing of Department Efficiency Committee: Notes on Water Hammer, Batcheller Papers, Box 12.

48. Operators Logs, Gorge Powerhouse; and "Reply to Testimony at Hearing of Department Efficiency Committee," International Brotherhood of Electrical Workers, September 6, 1924, Submitted to City Council September 17, 1924, Batcheller Papers, Box 12; and Bulletin No. 3: Larner-Johnson Hydraulic Valves, The Larner-Johnson Valve & Engineering Company, Philadelphia, PA, March 1923. In March 1980 the Johnson valves were replaced with Mitsubishi biplane valves. Powerhouse personnel expressed a belief in interviews that the these new valves do not work as easily nor as well as the fifty-six-year-old valves they replaced.

49.See Letter to Honorable Mayor and City Council from J. D. Ross, June 6, 1927, Folder 14-26, SLD 33-1.

50. D. C. Henny, "Classification, selection and adaptation of high dams," Transactions of the American Society of Civil Engineers November 1929:2327-36, p. 2333.

51.Donald C. Jackson, Great American Bridges and Dams, Washington, DC: The Preservation Press 1988, pp. 44-51.

52.T. W. Mermel, Register of Dams in the United States, New York: McGraw-Hill, 1958.

53. For additional information on Lars Jorgensen and the constant angle arch dam, see Lars Jorgensen, "The constant angle arch dam," Transactions of the American Society of Civil Engineers 78(1915):685-721; Robert Sutherland, "The scope of the constant-angle arch dam," Engineering April 10, 1936:387+; and Who's Who in Engineering, 1937.

54.See "Preliminary Report on a Program for Future Hydroelectric Power Development on Skagit River by the City of Seattle," November 1925, Skagit Engineering Commission, Box 16, Seattle Lighting Department Records, Accession 33-2 (hereafter SLD 33-2), University of Washington Libraries, and "Expansion of Seattle's Skagit River Project Urged," Journal of Electricity 55.3:108.

55.Folder 12-27, SLD 33-1.

56.Letter to Mayor and City Council, October 31, 1925, Folder 12-24, SLD 33-1.

57."Skagit and Toutle Undertakings in Washington," Electrical World January 23, 1926:215.

58."Select Site for Dam for Second Unit of Skagit Project," Journal of Electricity September 1, 1926:181.

59. Jorgensen to Ross, October 19, 1928, SLD 33-1, Folder 60A-31.

60. Homer T. Bone later served as U. S. Senator from the state of Washington and continued the fight for public power on a national level as a member of the Senate Committee on Interstate Commerce. For more on the public power movement in Washington, see Dick.

61. See, for example, Letter from Ross to Edwin J. Brown, June 8, 1922, or Memo from Ross to City Light Employees, June 16, 1922, SLD 33-1 Folder 11-30.

62. Ross to City Council, August 11, 1922, SLD 33-1 Folder 11-32. Unlike many public officials, Ross never minced words. For example, in a letter he wrote to the Wenatchee, Washington, Chamber of Commerce concerning Grand Coulee Dam, he told the Chamber "I think you are just dead from the neck up on the question of power." (SLD 33-1, Folder 69-37)

63. For more on the public power movement in Washington, see Dick.

64. Letter to City Council, October 13, 1925, SLD 33-1 Folder 12-23; "Site Chosen for Diablo Addition to Skagit Plant," Electrical World August 21, 1926:391.

65. Lighting Department employees were also encouraged to support candidates and referendums favorable to City Light and Ross's plans. In both letters and memoranda included in the Lighting Department records in the University of Washington Libraries Ross comments frequently on the perceived voting propensities of both current and potential employees.

66."Seattle Pays Damage Bill," Mount Vernon Daily Herald April 29, 1927, p.1.

67. The U.S. Congress created the Federal Power Commission in 1920 in response to pressure by conservationists concerned about irresponsible development of hydroelectric facilities. For the first ten years of its existence personnel had to be borrowed from its component departments -- War, Interior, and Agriculture -- and consequently the FPC was plagued by a weak administrative organization with no clear lines of managerial authority. See, for example, Robert D. Baum, The Federal Power Commission and State Utility Regulation (Washington, DC: American Council on Public Affairs, 1942); or the Federal Water Power Act of 1920, an act which authorized the commission to hire only one employee, an executive secretary.

68.Letter to W. C. Morse from Lars Jorgensen, June 6, 1927, Folder 60A-30, SLD 33-1.

69.Copy of telegram sent to Federal Power Commission, May 26, 1927, Folder 60A-30, SLD 33-1.

70. Letter, Lars Jorgensen to J. D. Ross, September 16, 1927; SLD 33-1, Box 60A, Folder 30. Jorgensen did not speculate about the specific identity of Mr. Davis, but by September 1927 Jorgensen had made several trips to the Skagit site and was familiar with the situation.

71.Letter to Morse, June 6, 1927, and Wing, pp. 84-90.

72. Although the Bone bill was defeated in 1924, Bone later succeeded in sponsoring legislation creating Public Utility Districts in Washington.

73.Homer T. Bone to J. D. Ross, October 7, 1927, Folder 57-32, SLD 33-1.

74. See, for example, F. W. Scheidenhelm, "The reconstruction of the Stony River Dam," Transactions of the American Society of Civil Engineers 81(1917):907-1015; Wegmann, 8th edition, pp. 698-700; or Lars Jorgensen, "Record of 100 dam failures," Journal of Electricity 44(1920):274-6, 320-1.

75.Wegmann, 1917, p. 64.

76. Wegmann, 1917, p. 135.

77. Multiple arch dams were also viewed with suspicion by some members of the engineering community, but in this instance the multiple-arches and buttresses apparently projected a greater sense of stability than one thin arch alone. Wegmann, pp. 135-36. In A History of Dams (London: Peter Davies, 1971) Norman Smith (p. 208) states it was actually the need for an enlarged reservoir which led to construction of a new dam at Bear Valley.

78. See, for example, Robert A. Sutherland, "Dam building reaches a climax," Engineering News-Record December 10, 1936:807-15.

79.See, for example, William Cain, "Stresses in masonry dams," Transactions of the American Society of Civil Engineers 64(1909):208-23, and William Cain, "The circular arch under normal loads," Transactions of the American Society of Civil Engineers 85(1922):233-48.

80. A. F. Parker, "The East Canyon Creek Dam," Transactions of the American Society of Civil Engineers 83(1919-20):574-98.

81.See, for example, F. A. Noetzli, "The relation between deflections and stresses in arch dams," Transactions of the American Society of Civil Engineers 85(1922):284-307.

82.The joint research committee of the American Societies of Civil, Mining, and Mechanical Engineers and the American Institute of Electrical Engineers.

83.See, for example, Walter J. Douglas, "Discussion: Multiple-arch dams," Transactions of the American Society of Civil Engineers 81(1917):892-4, p. 893.

84. See Wegmann, 1927, pp. 528-36; and Engineering Foundation Committee on Arch Dam Investigation, "Arch dam investigation," Proceedings of the American Society of Civil Engineers 54(1928):Part III, for a complete description of the Stevenson Creek experiments. The thirteen member committee consisted of both arch dam advocates and critics, was chaired by a past president of the ASCE, Charles Marx, and included such well-known and respected engineers as Fred A. Noetzli as secretary and John L. Savage, D. C. Henny, and Michael M. O'Shaughnessy as members. The test results should have been the last word on the arch dam controversy, but conservative engineers continued to resist the notion of thin arch dams and discussion in the professional journals remained intense. The 1930 issue of Transactions of the American Society of Civil Engineers, for example, published a lengthy symposium on high dams which continued the arch versus gravity debate, and a compromise in dam construction, the curved gravity dam, eventually emerged. Despite the outstanding safety record of thin arch dams, by 1936 Lars Jorgensen sounded a bit desperate when he offered to work at a bargain rate on the design of Ruby (later named Ross) Dam for Seattle City Light (SLD 33-1, File 69-37). N. J. Schnitter notes that arch dam construction in the United States declined sharply in the 1930s and did not revive until the 1960s, when the U.S. Bureau of Reclamation employed arch designs for Flaming Gorge, Yellowtail, and Morrow Point Dams. Schnitter blames the extreme caution displayed in the design for Hoover Dam for stifling interest in arch dam construction.

85."Concrete Arch Dam to be Tested to Destruction," Power August 4, 1925:191.

86. Letter to J. L. Savage from George H. Moore, August 19, 1927, Folder 15-11, SLD 33-1. Savage was a member of the Arch Dam Investigation Committee and Moore was apparently hoping to solicit inside information before the test results were officially released.

87. Jakobsen's example assumed that, in a V-shaped canyon, a gravity dam 200 feet tall would require a base 136 feet wide, a constant radius arch dam a base 55 feet wide, and a constant angle arch dam would have a base only 19.5 feet wide, although Jakobsen failed to draw attention to the fact that while both gravity and constant radius arch dams diminish in thickness as they increase in height, constant angle arch dams may have sections toward the middle of the dam which exceed the base in width. B. J. Jakobsen, "Volume relation of constant angle arch dams and gravity dams," Engineering and Contracting December 8, 1920:554-557.

88.B. J. Jakobsen, "Volume Relation of Constant Angle Arch Dams and Gravity Dams," Engineering and Contracting December 8, 1920:554-557, and "Design Details and Field Methods on Thin Arch Dam," Engineering News-Record 84.10:474-476.

89. See, for example, Letter, J. D. Ross to John S. Swenson, September 8, 1927, Folder 15-13, SLD 33-1.

90. Letter, Jorgensen to Ross, September 16, 1927, and November 3, 1927, SLD 33-1 Folder 60A-30.

91."Grants Diablo License," Electrical World 90.16:804, and Letter from J. D. Ross to V. E. Wren, September 29, 1927, Folder 15-17, SLD 33-1.

92.See "Seattle asks Federal License for Skagit Extension," Electrical World 89.5(1927):266.

93. Ambursen Dams, designed by the Ambursen Hydraulic Construction Company of Boston, Massachusetts, were buttress dams which the company advertised as being suitable for foundations of varying characters. See, for example, Edward Wegmann, The Design and Construction of Dams, 6th edition (New York: John Wiley & Sons, 1918), pp. 210-20, for a more complete description of Ambursen and other buttress type dams.

94."Good Site for New Skagit River Dam Reported Found," Electrical World 89(1927):625. At one time Ross had suggested a site further upriver from the existing dam, but it would have required construction of a new intake and an addition to the power tunnel.

95.Letter to City Council, June 6, 1927, Folder 14-26, SLD 33-1.

96."To Speed up Diablo Dam," Electrical World, 90(1927):375.

97."Seattle Council Approves Total Skagit Bond Issue of $8,650,000," Electrical World 90.20(1927):1010, and "Seattle's City Engineer Thinks Ambursen Dam Too Costly," Electrical World 90(1927).

98."Seattle Lighting Department Records Progress," Electrical World 91(1928):523.

99.See Letter to Honorable Mayor and City Council, June 4,1927, Folder 124-1, SLD 33-1. "Two Plans for Developing Skagit Considered by Council," Electrical West February 1, 1928:409.

100."Seattle Abandons Plan for Dam at Hanging Rock," Electrical West July 1, 1929:39.

101."Platform Lift on Incline Raises Cars 313 Ft.," Engineering News-Record July 19, 1928:84-86.

102. Approximately 3500 feet of cable wound on two 7-1/2 ft. drums moved the platform. The hoist, a Model D Lilly Hoist Controller, was powered by a 400 horsepower, 2200 volt, three phase Allis-Chalmers motor. Most of the details of the incline were developed by J. H. Quense, a junior water supply engineer for the city. It was estimated the incline could carry enough sand, cement, and aggregate to supply materials for 1600 cubic yards of concrete daily.

103."Construction Ingenuity Displayed at Diablo Dam," Engineering News-Record August 29, 1929:320-324, and "Handling Aggregates and Cement for Diablo Dam," Engineering and Contracting January 1930:41-42.

104."Diablo Dam, Seattle, Washington," Western Construction News February 25, 1929:121-2.

105.See "Coffer Dam Washed Out," Mount Vernon Daily Herald May 21, 1928, p.1, "Time Extension Requested by Contractors on Diablo Dam," Engineering News-Record December 12, 1929, p. 200, "Diablo Dam and Tunnel, Seattle, Washington," Western Construction News December 25, 1929, p. 684, and Letter to City Council from Winston Bros., April 8, 1931, Seattle

Lighting Department Records Accession 33-2, University of Washington Libraries (hereafter SLD 33-2), Box 50, File 1260-b.

106."Diablo Dam Dedicated," Power 72(1930):478.

107.Robert A. Sutherland, "Dam Building Reaches a Climax,." Engineering News-Record December 10, 1936, pp. 807-815, and Mermel.

108.Lars Jorgensen, "The Diablo Constant-Angle Arch Dam," Engineering July 7, 1933:2.

109."Seattle Dedicates Diablo Dam," Western Construction News September 10, 1930: 435.

110.Ross to Thomson, September 23, 1930, Reginald H. Thomson Papers, Part II, Folder 4-3, University of Washington Libraries.

111.Thomson to Ross, October 1, 1930, R. H. Thomson papers, Part II, 4-3. Thomson's comments about the appearance of the building to the general public coincided with an overall increased awareness of the importance of architectural design in power plant construction. Powerhouse designers were initially more concerned with achieving the most efficient plant layout -- see, for example, Alton Adams, Electric Transmission of Water Power (New York: McGraw-Hill Book Co., 1906), pp. 83-102 -- than with aesthetics. This changed in the 1920s as both engineers and architects realized the importance the external appearance of a facility played in areas such as employee morale and public relations. In "It pays to build beautiful powerplants" W. H. Evans (Power Plant Engineering 33(June 1, 1929):645-7) argued that a well-designed plant contributed to worker productivity as beauty and efficiency went hand in hand. See also A. H. Markwort, "Art in the electric industry," Power Plant Engineering 33(February 15, 1929):243-8; D. DesGranges, "Designing of power stations," Architectural Forum 51(September 1929):361-72; W. R. Fargo, "Architecture as a factor in plant design," Power Plant Engineering 35(April 15, 1931):464-5; "Power plants that are ornamental as well as useful," Power 52(August 10, 1920):209; or "Attractive power plants need not be costly," Power Plant Engineering 31(June 1, 1927):609-15.

112.Thomson papers, Part 1I, 4-4, and Seattle Lighting Department Annual Report 1933, p. 14.

113.A. Comeaux to Eugene Hoffman, August 7, 1940, SLD 33-2, Box 50, File 1260-b.

114.Letter to Carl Thompson, May 1925, Folder 12-7, and Letter to M. G. Tennent, March 7, 1927, Folder 14-8, SLD 33-1.

115.Letter to John Dore, Box 50, Memo, Folder 1-4, SLD 33-2.

116."Seattle Skagit Loan Held to Be Unlikely," Electrical West 72.1:40.

117. As the hydroelectricity industry entered the 1930s it had already achieved what historians of technology characterize as "maturity" but that maturity was fairly recent. In 1906, when Alton D. Adams wrote Electric Transmission of Water Power, horizontal shafting for generators was common

and the vertical shaft was a rarity. When Puget Sound Traction Light and Power expanded its White River plant in 1918, the 25,000 hp. Francis turbine installed was the largest in the world. It was direct connected to the generator with a horizontal shaft. Only eight years later turbines of 50,000 hp were common and the vertical shaft had become the accepted configuration, but the industry continued to push for ever larger units. See, for example, Richard F. Hirsh, Technology and Transformation in the American Electric Utility Industry. Cambridge: Cambridge University Press, 1989, 184-189. Alton D. Adams, Electric Transmission of Water Power, New York: McGraw-Hill, 1906, 83-93. Arnold Pfau, "Largest High Head Francis Turbine," Power 47.6(1918), 174-177. "Activity in the Field of Water Power," Power 63.1(1926), 20-24.

118. Hirsh, pp. 73-75.

119."300-Ton Power-House Crane," Engineering April 14, 1933, 416, "Seattle Has Large Crane," Electrical World September 10, 1932, 327, and "Largest Crane Goes to Diablo Dam," Electrical West October 1, 1932, 68.

120."Seattle Municipal Bonds," Electrical World April 21, 1934, 600, and "Seattle Sells Bonds to Complete Skagit River Power Project," Engineering News-Record April 26, 1934, 553.

121."Seattle Proposes to Resume Work on Skagit Project," Engineering News-Record May 31, 1934, 722.

122."Seattle City Light Starts Construction," Electrical West July 1934, 35; "Diablo Contract Awarded," Electrical World September 29, 1934, 512; "Diablo Contract Forfeited," Electrical World October 13, 1934, 636, and "Seattle to Install Diablo Generating Equipment," Electrical World July 6, 1935, 1702.

123. "Seattle Plans 160,000-Hp. Plant at Reflector Bar," Electrical West, March 1, 1927, p. 176.

124.Seattle Lighting Department Annual Report 1936, 16. Roosevelt's button pushing was purely ceremonial, of course, as the Operators' Logs show that operators began filling the power tunnel and penstocks on September 12, opened the head gate and butterfly valve on September 22, and began running and testing Generator 32 that same day.

125.Operators' Log, Diablo Powerhouse.

126.Operators logs for Diablo Powerhouse in the 1930s indicate doors were unlocked so the general public could have entered the building, but make no mention of formal tour groups, and descriptions appearing in newspapers and magazines prior to World War II indicate Diablo Powerhouse was not included in the standard package tour.

127.Ross to R. H. Thomson, September 23, 1930, Thomson Papers, Part II, Folder 4-3.

128.Lewis Mumford, Technic and Civilization (New York: Harcourt, Brace and Company, 1934).

129. "Seattle buys land in Canada for hydro-power reservoir," Electrical World October 19, 1929:803.

130. Memorandum, Box 1, Folder 4, SLD 33-1. See also "Power project near Seattle advanced for RFC loan," Engineering News Record April 20, 1933:511; "Seattle seeks aid for Ruby Dam construction," Electrical World April 22, 1933:503; and The Bonneville Spark March 1939, p. 17.

131. "Skagit river development to cost only $90 per Kw," Power Plant Engineering May 1937:302-3. The major federal projects of the early 1930s -- e.g., Boulder, Bonneville, and Grand Coulee -- all utilized gravity designs, although Boulder was a curved gravity dam rather than a straight one. See, for example, Schnitter, for a more extensive discussion of the influence of federal projects on dam design.

132. Lars Jorgensen, "Comparison of Ruby Dam designs," Engineering News-Record October 14, 1937:633-4.

133. "Ruby Dam, Seattle," Engineering News-Record September 23, 1937:21.

134. "First phase of Ross Dam work nears completion," Electrical World August 5, 1939:5.

135."Ross Dam built in isolated Skagit gorge," Engineering News-Record October 12, 1939:47-52; "Skagit project," Engineering News-Record February 15, 1940.

136. See "FPC approves adding height to Ross Dam," Electrical World 188(August 15, 1977):28; Bill Barich, "Our far-flung correspondent: Ross Dam and Copper Creek," New Yorker 57(January 4, 1982):57+; M. Gray, "A wilderness preserved," MacLeans 96(April 11, 1983):32.

137. "Bids for freezing river bed swing Washington dam job," Engineering News-Record 154(February 17, 1955):234; "Ice dam to be built in the Northwest: Seattle City Light will freeze the riverbed," Electrical World 144(September 26, 1955):32; "New technique used for High Gorge ice barrier," Engineering News-Record 162(January 22, 1959). See also Letter from Cascade Constractors, Inc., and Alton V. Phillips to the Seattle Board of Public Works, September 7, 1949, SLD 33-2 Box 39, for a lengthy discussion of the horrendous working conditions prevailing during construction of the second Gorge Dam.

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APPENDIX A -- TECHNICAL INVENTORY

DIABLO POWERHOUSE INVENTORY

HEADWORKS:

Diablo Dam is a constant angle single arch dam with two gravity abutments. The dam is 389 feet high from bedrock to its crest, has a crest 16 feet wide and 1,170 feet long. The arch portion is 540 feet long and the gravity abutments total 630 feet. The gravity sections have a base width that is 85 percent of their height. The Constant Angle Arch Dam Company of Berkeley, California, designed the dam, and Winston Brothers of Minneapolis were the primary contractors. Construction began January 1, 1928, and officially ended with the dam's dedication on August 27, 1930.

There are 19 spill gates, Tainter type, 20 feet wide and 18 feet high.
Gates 1, 2, 3 were motorized in the mid-1960s and can be controlled from dam, powerhouse, or Seattle.
Gates 4 through 19 are manually operated and are lifted by means of a rail mounted hydraulic hoist.

Valve house: Four relief valves at elevation 1045 are accessible by elevator or ladder.
1 - Larner-Johnson hydraulic valve, 6-ft diameter
3 - butterfly valves (6.5-ft diameter)
All four valves were supplied by the Pelton Water Wheel Company.
4 - 8' x 10' broome gates on upstream side lifted by a Shepard Niles roller bearing hoist, 3-3/4 tons, purchased May 22, 1953.

Head gate - 15' x 20 ' broome gate
cable drum hoist

Power tunnel - 19-1/2 foot diameter.
1990 feet in length
1800 feet are concrete lined
190 feet steel lined
Bifurcates into two penstocks, 290 feet long, 15 feet in diameter.
Just before bifurcation 5 foot penstock tapped in to supply water to house units 35 & 36.

POWERHOUSE:

Sump pumps for dewatering powerhouse:
6-inch pipe
2 - Worthington 15 hp 1150 gpm centrifugal pumps powered by Westinghouse motors.

Waste oil sump pump:
1 - 15 gal/min Worthington 2 hp motor pump

Lower oil room:

Oil Tanks:

Tank # 1 -- 3200 gallon clean lubricating oil for actuator oil system
Main and service units for gravity supply lubricating oil tanks at elevation 942.5
This tank carries in storage at all times complete oil charge for main unit actuator system

Tank # 2 -- 3200 gallon
Receives oil from all actuator and lubricating oil systems. Normally empty at all times.

LeRoi Air Compressor
Model 50SS

2 - Gardner Denver 2-1/2 hp vertical air compressors
200 lbs/sq in
870 rpm

1- Quincy Air Corporation vertical air compressor

2 - gravity oil pumps
Worthington Rotary Pump powered by Lincoln ac 2 hp motor

1 - Zurn Air and Gas Dryer (compressed air dryer)

Lubricating oil purifier -- Sharples Centrifuge
500 gallons per hour -- No filter. Feeds from tank #2 and returns to tank #1, or reverse.
Feeds from tank #5 and returns to tank #1 or 2.

Cooling water gallery:

3 - Westinghouse Type CS 30 hp motors for cooling water pumps. These pumps were installed to draw water from the tailrace into the cooling water system for the generators in the event water from the penstocks was not available. As the only time water from the penstocks is not available is when the generators are not running, rather than being used to pump cooling water, the pumps are utilized to dewater the draft tube area and make it accessible for maintenance and repairs after the stoplogs are dropped.

1 - S. P. Kinney strainer powered by Reliance 480 v 3 phase 3/4 hp motor. (This is a motor driven sleeve type worm gear reducer.)

2 - Limitorque automated scroll case gate valve with 20 hp motor.

2 - Siemens Elmo Liquid Ring Compressors
885 rpm powered by Allis Chalmers induction motor (2200 volt, 300 hp, 3 phase)

Governor oil pumps -- Units 31 & 32

W.E. Quimby pumps powered by Westinghouse Type CS 60 hp, 220 volt, 1155 rpm 3-phase motors
Accumulator tanks - S. Morgan Smith
Capacity - 800 gallons
Test pressure -- 300 lbs/sq in.
Maximum working pressure -- 200 lbs/sq in.
Oil sump tanks -- capacity 2500 gallons

Transformer banks (House units):

Bank 35 - 50 kw 3 phase 2200 to 480
Bank 36 - 50 kw 3 phase 2200 to 240/120

Upper oil room:

Tank # 3 -- 12,000 gallons -- Clean transformer and circuit breaker oil. Sufficient oil to fill one transformer is stored in this tank at all times.

Tank #4 -- 12,000 gallons -- Receives drains from all transformers and circuit breakers. Normally empty.

Tank #5 -- 1,000 gallons -- Receives aggregate station waste oil from oil collecting sump. Oil may be purified or transferred to outlet at roadway.

1 - Westinghouse electric oven Type 1-70 2000 watt
(Used for drying and curing plates for oil filter)

1 - Worthington pump size 80-C

1 - Bowser oil filter system for cleaning lubrication oil.

1 - Hipotronic Oil Arc Tester purchased in 1984

Transil oil purifier -- Sharples Centrifuge -- 1200 gallons per hour with filter press.
Feeds from tank #4 and returns to tank #3 or the reverse.
Feeds from transformer or breaker and returns to same or to tank #3 or 4.

1 - Westinghouse Oil Arc Testing Set (original equipment replaced by Hipotronic Oil Arc Tester in 1984)
capacity 17 gallons oil
full load in one hour
Style No. 533100D

1- CO_2 fire suppression system -- 48 tanks (routing valve racks by Ansul Company, Marinette, WI)

HOUSE UNITS:

	Unit 36	Unit 35
Turbine -	S. Morgan Smith	S. Morgan Smith
	2200 hp	2200 hp
	720 rpm	720 rpm
	306 head	306 head
Generator -	Westinghouse	Westinghouse
	1500 kva	1500 kva
	2400 volts	2400 volts
	361 amp	361 amp
	80 p.f.	80 p.f.
	3 phase	3 phase
	60 cycles	60 cycles
	720 rpm	720 rpm
	Exc. amps 102	Exc. amps 102
	Exc. volts 125	Exc. volts 125

Woodward governors

Accumulators and oil sump for governors for house units - S. Morgan Smith

Spare exciter:
Westinghouse DC generator -- SN 8087109
280 kw
250 volts
1120 amps
880 rpm
Westinghouse CS motor -- SN 8087119
420 hp
2300 volts
880 rpm
Westinghouse DC generator -- SN 8170273
12 kw
250 volts
48 amps
880 rpm

Butterfly valves -- Units 31 and 32
Pelton Water Wheel Company -- August 15, 1931

14 ft. diameter
tested to 4000 lbs/sq in., 327 ft. head
22-inch operating cylinder

Relief valves -- S. Morgan Smith

Units 31 and 32 -- Original (nameplate) ratings
Turbines: S. Morgan Smith
327 head
90700 horsepower
171.5 rpm
Serial numbers -- 8580, 8581

Generators: 66700 kva
13800 volts
2790 amps
90 p.f.
171.5 rpm
Exc. 900 amps
Exc. 250 volts
Serial numbers 8087115, 8087116

ASEA Governors -- installed in 1963

Machine Shop:

1 - Hydraulic press
1 - 3/4 hp bench grinder
2 - 1/3 bench grinder
1 - Lodge & Shiply 22 inch lathe
1 - South Bend Lathe, Inc. drill press
1 - Cincinnati Bickford shaper
1 - Gould and Eberhart mill
1 - Delta Rockwell 11 inch bench lathe
1 - Delta Rockwell drill press
1 - Armstrong-Blum bank saw (patented July 17, 1919)
1 - Balder 5 hp. grinder
1 - Wilton Square Wheel belt grinder
1 - Milwaukee 1 hp grinder

Battery Room: Main Station Service
58 lead calcium batteries
(Batteries are charged by a 132 volts C & D Batteries Division battery charger)

Rheostat Bank -- Spare Exciter. Original equipment, manufactured by Westinghouse. Control rack for rheostat also by Westinghouse.

Motor Generator -- spare battery charger

Original equipment by The Electric Products Co.

Battery Room: Communications system
24 lead calcium batteries for communications
23 lead calcium batteries for telephones

52.8 volts C & D Batteries Division battery charger

Westinghouse PRX voltage regulators for Units 31 & 32.

Gravity Oil Room:

Tanks 6 & 7 -- 450 gallons each -- supply oil to lubricating systems of all main and service units. Charges all lubricating oil systems. Float switch charts Pump C and keeps tank full at all times.

Westinghouse Single Phase Oil Insulated Water Cooled Transformers
22500 kva, 55^{o} rise, 7100 gallons oil
November 30, 1931

Stop Log Hoist -- Cable Winch can lift 8000 pounds
Draft tubes stop logs -- 6400 pounds
Relief valve stop logs -- 7000 pounds

Transformer bank 38 (Ross Tie)
Allis-Chalmers (Indoor Type put outside in 1940s "temporarily" and has remained there ever since)
1000 kva 1 phase 60 cycles, 2.5 kv to 26 kv

Oil Requirements for Station:

Actuator charge -- Unit 31	2600 gallons
Actuator charge -- Unit 32	2600 gallons
Governor charge -- Unit 35	50 gallons
Governor charge -- Unit 36	50 gallons
Lube oil charge -- Unit 31	250 gallons
Lube oil charge -- Unit 32	250 gallons
Lube oil charge -- Unit 35	60 gallons
Lube oil charge -- Unit 36	60 gallons
Gravity system lube oil tanks	1300 gallons
One actuator system charge	2600 gallons
Total lubricating oil	9820 gallons

7 transformers @ 7330 gallons	51310 gallons
8 oil circuit breakers @ 16000	128000 gallons

Station service transformers	830 gallons
Bank 38 transformers	1240 gallons
Total transil oil	188710 gallons

Incline Railway -- Lilly Hoist Controller Model D
Allis-Chalmers 400 hp, 2200 volt, 3 phase motor
Westinghouse Resistors -- set of 12
423 volts
429 amps

GORGE POWERHOUSE INVENTORY

HEADWORKS:

Thin arch dam with a gravity section. The total length of the dam is 670 feet, the arch section is 450 feet long and the gravity section 220 feet. Spillgates and spillways are located in the gravity portion of the dam. The crest is 16 feet wide, the dam is 300 feet high from bedrock, the gravity section is 170 feet thick at its base and the arch section is 70 feet thick at its base. Design work on the dam was done by the consulting firm of J. L. Savage and construction was done by Merritt-Chapman & Scott Corporation of New York. Work began on Gorge High Dam in 1955 and was completed in 1961. The dam was formally dedicated on January 6, 1961.

Headgate -- vertical lift fixed wheel gate -- 26'9" high -- weighs 200 tons and is raised with a hydraulic hoist.
Minimum water elevation -- 825.0
Gate sill elevation -- 795.0
Spill gates (2) -- vertical lift fixed wheel gates -- 47 feet by 50 feet
Log chute -- 6 feet wide by 7 feet high with a fixed wheel gate
Outlet gates (2) -- 8.75 feet by 8.75 feet, fixed wheel gates
Stop logs for outlet gates -- 13.83 feet by 11.29 feet
Power tunnel -- 20.5 feet in diameter
Surge tank -- 21.5 feet in diameter with a restricted orifice (15'2")

POWERHOUSE:

Unit 24 butterfly valve -- 15 feet in diameter
Hydraulic system for butterfly valve:
Vickers, Inc. Model #VK-2325-3
1 ac pump
1 dc pump
Hydraulic cylinder -- butterfly valve (4/26/1950)
Pelton Water Wheel Company
2400 lbs per square inch

Sump pumps -- Worthington vertical turbine pumps (2)
Size 12 QHE

Circuit breaker air compressors -- (2)
Westinghouse Type Y 3 hp 10.6 cfm
Joy Model 50-E 50 hp

Units 21, 22, 23 -- Butterfly valves -- March 1980
Mitsubishi Biplane Type Butterfly valve -- 120 inch diameter
(Replaced the Larner-Johnson valves installed as part of the original construction of the powerhouse)
Servomotor diam 9.84 inch

stroke 42.14 inch
Working oil pressure 1580-1700 psi

Manual jacking system -- Watson-Stillman Co., Roselle Park, NJ
Governor oil pump/tank -- Woodward Type 200 -- April 1987
Mitsubishi Electronic Control panels -- March 1980
Westinghouse Air Circuit Breakers -- 14400 volts, 60 cycle, 2000 amps

DeLaval Separator Company -- Industrial Centrifuge

Unit 24 Grounding transformer bank -- Westinghouse 150 kva, 12000 to 240 volts

Westinghouse Air Circuit Breaker for Unit 24 -- 4000 amps

Transformers -- Westinghouse -- single phase
Bank 22 -- 3 31,000 kva transformers
3 25,000 kva

Stop log hoist -- rated at 4 tons -- Unit 24
Stop log hoist -- 3 tons -- Units 21, 22, 23

Nameplate ratings Unit 24:

<u>Generator</u>: Westinghouse

66,700 kva	Exc. amps 905
11,000 volts	Exc. volts 250
3500 amps	
90 power factor	C° rise: Stator 60°
3 phase	Rotor 60°
60 cycle	
163.7 rpm	

<u>Turbine</u>: Allis Chalmers
82,500 hp.
163.7 rpm
280 foot head

The generator for Unit 24 was rewound in 1960 and the rating increased to 78,000 kva. It is being rewound again in 1989 and when completed will have a rating of 102,000 kva. The turbine received a new runner when the Gorge High Dam was built in 1959.

Woodward governor unit -- Unit 24

Name plate ratings:

Unit 23: <u>Generator</u>	<u>Turbine</u>
Westinghouse	S. Morgan Smith Co.
33000 kva	Head 325 feet
11000 volts	45000 hp
1732 amps	257 rpm
90 p.f.	

257 rpm
Exc. 580 amps
Exc. 250 volts

Units 21 & 22: Westinghouse	S. Morgan Smith Co.
30000 kva	Head 325 feet
90 p.f.	45000 hp
257 rpm	257 rpm

Woodward Governors, now automated

Relief valves units 21, 22, and 23: Needle type synchronous by-pass. (Unit 24 does not have a relief valve.)

Machine Shop: Glausing Colchester Lathe
17-inch
12.55 hp motor
400 amps
Clausing drill press

Transformer bank 27
Westinghouse 3 phase
3000 kva, 11000 to 6600 volts

Exciters -- 21, 22, 23 -- Westinghouse
160 kw
250 volts
257 rpm

OIL TANKS:
Tank 1 -- 5000 gallons filtered transil oil
Tank 2 -- 1000 gallons filtered transil oil
Tank 3 -- 1400 gallons unfiltered governor and lube oil
Tank 4 -- 1400 gallons unfiltered governor and lube oil
Tank 5 -- 1400 gallons filtered governor and lube oil

Gravity oil system removed and new governor and lube oil distribution system installed in 1987.

BRIDGE: The vehicle bridge across the Skagit River from Highway 20 to Gorge Powerhouse is a two-span Pratt truss iron structure and is a former railroad bridge constructed prior to the construction of the addition to the powerhouse. The bridge is one-lane wide with a pedestrian walkway and is 308 feet long.

NEWHALEM POWERHOUSE AND DAM

The Newhalem Dam is a low concrete diversion dam on Newhalem creek built in the late 1960s to replace the original timber crib diversion dam. The power tunnel is approximately 5 ft by 7 ft, 2770 feet long, and unlined. A steel penstock 500 feet long connects the power tunnel to the power house. The penstock bifurcates just before entering the power house and supplies water to two Pelton impulse turbines direct connected with a horizontal shaft to a 2500 kva Westinghouse generator. The turbines and generator were rebuilt and automated in the late 1960s after the original wooden powerhouse burned down. The current structure is a one-story wooden frame building with a concrete slab floor, but is not an exact replication of the original structure.

ROSS POWERHOUSE INVENTORY

HEADWORKS:

Ross Dam is a constant-angle thin arch dam 540 feet high. The crest is 1300 feet long and 33 feet wide. It was built in four steps, with construction on the first step beginning in 1937 and ending at the present height in 1947. Preliminary design work was done by the engineering firm, The Constant Angle Arch Dam Company, which designed Diablo Dam. Following the death of Lars Jorgensen in 1937, additional design work was by the consulting firm of J. L. Savage.

Headgates (2) -- fixed wheel gates which each weigh 210 tons.
Spillgates (12) -- Tainter gates which pivot on a 21.5 ft. radius.
Relief valves (2) at elevation 1340 -- butterfly valves with a 6 ft. diameter with broome gates on the upstream side.

POWERHOUSE: Ross Powerhouse is 200 feet high from sump floor to generator room ceiling. The bulkhead between the electrical gallery and the turbine pit walkway is 29 feet of concrete. The building is 288 feet long.

GENERATORS: All four units are rated at 100,000 kva, .9 power factor, 13,000 volts, 60 cycles, and 150 rpm. The units are all three-phase Westinghouse units with 48 poles and are star connected with a ground reactor off the neutral.
Each unit has four bearings -- upper guide, lower guide, thrust and turbine.
Rotor diameter -- 27.6 feet
Air housing diameter -- 42.7 feet
The generators are air-cooled.

TURBINES: The turbines for Units 42, 43, and 44 were designed and built by the Baldwin Locomotive Corporation. The turbine for Unit 41 was designed and built by Newport News Corporation. The operating heads and limits are as follows:
Minimum head -- 265 feet and 72,500 hp.
Rated head -- 355 feet and 120,000 hp.
Maximum head -- 395 feet and 133,500 hp.
Turbine efficiency varies between 92 percent and 94 percent when operating near the rated load.

The runner diameter is 14.58 feet for the Baldwin turbines and 20.25 feet for the Newport News turbine.

The actuator and lubricating oil systems for each unit are independent. The turbine bearing oil reservoir holds 125 gallons, the lower bearing reservoir holds 90 gallons, and the thrust and upper bearing reservoir holds 1100 gallons. The governor system is by Woodward Governors.

Two storage tanks for the lube oil system hold 3000 gallons of filtered oil, 3000 gallons of unfiltered, and oil is passed through a DeLaval industrial centrifuge for cleaning. The lubricating oil pump can pump 50 gpm at 125 psi.

Two storage tanks for the transformer insulating (transil) oil hold 7500 gallons of filtered oil and 7500 gallons of unfiltered. Each 70,000 kva transformer requires 7100 gallons of transil oil. The transil oil pump can pump 100 gallons per minute at 50 psi.

TRANSFORMERS:

General Electric (6) one phase 60 hz -- Banks 42-44
Voltage rating 241,500 ground
KVA rating 70,000 continuous 55°C rise
Forced oil cooled with 220 gallons per minute of 25°C cooling water
Subtractive polarity

Westinghouse 3 phase type class OA/FA -- Bank 46
3750/5000 kva

Maloney 3 phase 60 hz 3000 kva -- Bank 48
Class OA Type TC-MA

HISTORIC PHOTOGRAPHS FROM SEATTLE CITY LIGHT

In addition to the photographs taken by the HAER photographer, prints of the following historic photographs are contained in the Field Notes for HAER Project WA-24. Negatives of these photographs are on file at Seattle City Light. The Seattle City Light file number for each photo is in brackets before the description.

1. [D(29-12-1)3] Diablo Dam under construction showing intake area for relief valves.

2. [D(6-28-30)4] Construction scene Diablo dam.

3. [D(29-3-29)2] Broome gates for Diablo dam relief valve intake.

4. [D(29-9-2)3ABC] Panorama of dam construction.

5. [D(29-10-1)1] Upstream of dam during construction with cofferdam in foreground.

6. [LD-40] The Harnischfeger bridge crane being placed in position in Diablo powerhouse, May 1935.

7. [LD-47] Long shot of crane and trolleys in place in Diablo Powerhouse.

8. [LD-157] Powerhouse and Diablo Camp; an overall view taken on October 1, 1935.

9. [LD-185] Scroll case with workmen, Diablo Powerhouse, October 1935.

10. [LD-208] Interior of powerhouse with scroll cases in place on October 28, 1935.

11. [LD-275] Scroll cases and start of forms.

12. [LD-303] A butterfly valve for Diablo Powerhouse. Butterfly valves were manufactured by the Pelton Water Wheel Company.

13. [LD-318] Metal reinforcement for the generator pedestals, Diablo Powerhouse.

14. [LD-348] January 18, 1936, Diablo Powerhouse: Generator rotor shaft -- weight 15 tons.

15. [LD-373] Generator rotor with part of laminations assembled, Diablo Powerhouse, February 1936.

16. [D-436] Generator rotor and shaft with cribbing, Diablo Powerhouse, March 1936.

17. [LD-453] Conduit in floor slab Unit 32, Diablo Powerhouse, April 1936.

18. [LD-464] Relief valve piston, Diablo Powerhouse, April 1936.

19. [LD-472] Turbine runner Diablo powerhouse. April 28, 1936.

20. [LD-476] Setting runner in place, Diablo Powerhouse, May 5, 1936.

21. [LD-485] Setting top plate assembly in place - Unit 32, Diablo Powerhouse, May 8, 1936.

22. [LD-493] Setting section of generator bed plate in place. Diablo Powerhouse, May 11, 1936.

23. [LD-516] Setting section of generator stator in place, Diablo Powerhouse, May 28, 1936.

24. [LD-566] Interior of power tunnel, July 1936, Diablo Powerhouse.

25. [LD-586] Interior shot showing work in progress Diablo Powerhouse August 1936.

26 - 28. [LT-174, LT-187, LT-196] Working on transmission lines; linemen used hand tools to build transmission towers on almost sheer mountainsides.

29. [L-70] Gorge Powerhouse ca. 1930.

30. [L112] Tourists strolling on roadway on crest of Diablo Dam during the early 1930s.

31. [L-323] Laying cement in switchyard for Diablo Powerhouse in May 1935.

32. [L-367] Piece of crane being positioned in Diablo Powerhouse in 1935.

33. [D-314] Top plate and bearing housing, Diablo Powerhouse, January 1936.

34. [E-229] Construction scene, interior of Gorge Powerhouse, January 12, 1923, showing Units 1 and 2 (now referred to as Units 21 and 22) from the west.

35. [E-506] Scroll case and Johnson valve Unit 21, Gorge Powerhouse.

36. [E-616] Rotor and spider for #1 (21) generator, Gorge Powerhouse in 1923.

37. [E-664] Speed ring Unit 2 (22), Gorge Powerhouse, 1923.

38. [889] Generator floor view, Gorge Powerhouse, 1924.

39. [SP-2826-GHD] Looking down on freeze point during construction of Gorge High Dam. The second Gorge Dam is shown to the right.

40. [SP-2593-GHD] The second Gorge Dam, constructed in the late 1940s.

41. [L-624] A truck crossing the suspension bridge at Ruby Dam (now known as Ross Dam) during the initial construction in 1938.

42. [L-680] Excavation in the Glory Hole at the site of Ruby (Ross) Dam in 1938.

43. [RD-172] General view of the construction site just after concrete was first poured for Ruby (Ross) Dam.

44. [RD-186] March 1939: View from bridge of concrete form at Joint 17 on Ruby (Ross) Dam.

45. [RD-210] View of construction camp for Ruby Dam in 1939.

46. [RD-238] June 27, 1939: Inspection gallery form for Ruby Dam.

47. [LT-1072] Concrete mixing plant with loading platform for construction of Ruby Dam.

48. [RD2-184] September 14, 1944: Left bank with engineering

notes showing plans for future work.

49. [SP-1175-RPH] August 10, 1951: Pouring operations at fender wall -- note hardhats and 8-yard bucket, neither of which were present at previous construction on the Skagit.

50. [SP-1446-RPH] October 13, 1951: Pouring operations north end of pit. This marked the start of the actual construction of Ross powerhouse.

51. [SP-2408-RPH] May 3, 1952: Area to be filled with second stage concrete above Ross Powerhouse Unit 44 draft tube liner looking downstream and showing the method of anchoring the liner.

52. [SP-2502-RPH] June 28, 1952: Maneuvering first beam of the 170-ton bridge crane onto rails positioned on superstructure columns at Ross Powerhouse.

53. [SP-2701-RPH] August 11, 1952: Welder on assembly of #2 spillway gate on Ross (formerly Ruby) Dam. The gate pivots on a 21.5-foot radius.

54. [SP-3143-RPH] November 15, 1952: Wicket gate installation at Ross Powerhouse.

55. [SP-3789-RPH] April 27, 1953: Head gate erected and being bolted up within structural steel framework of hoist tower at Ross Dam.

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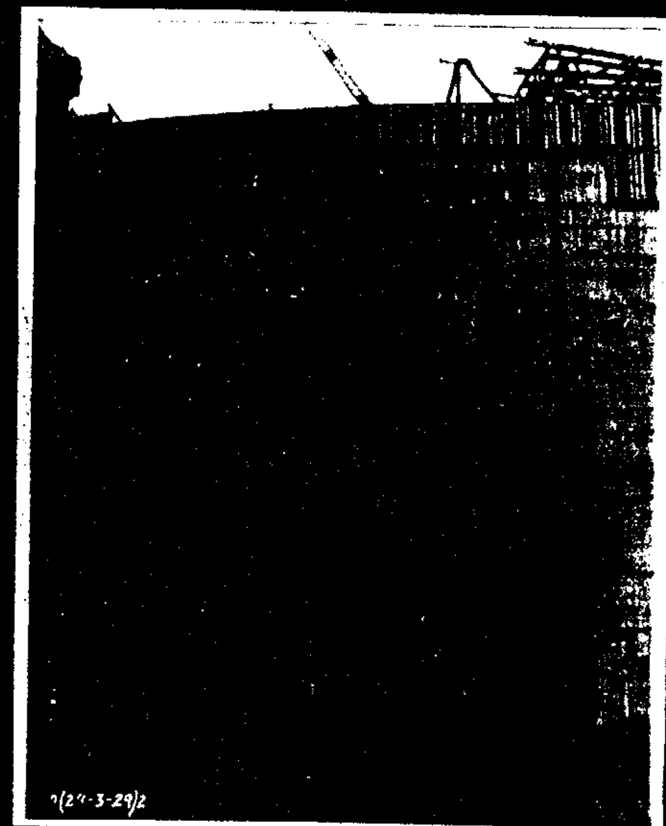

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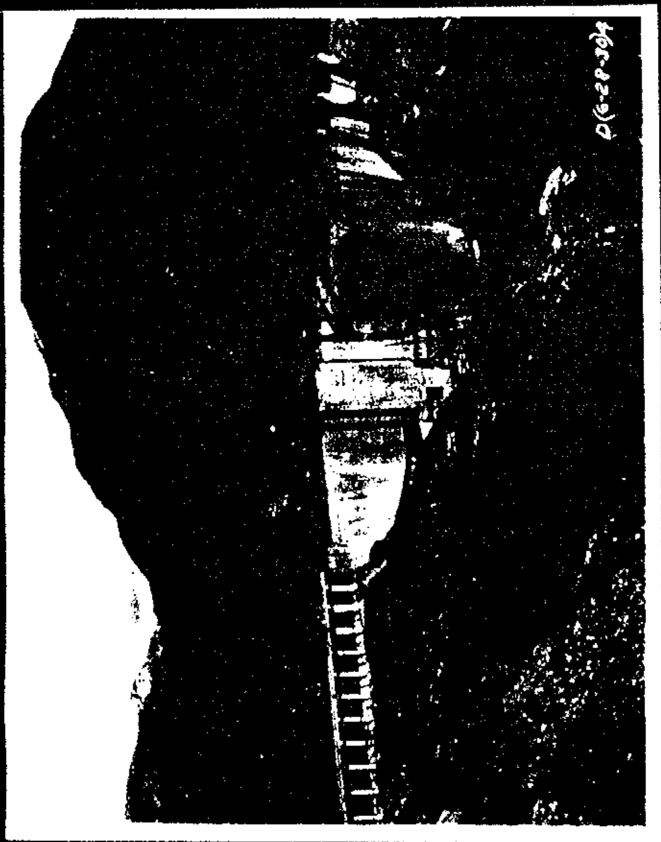

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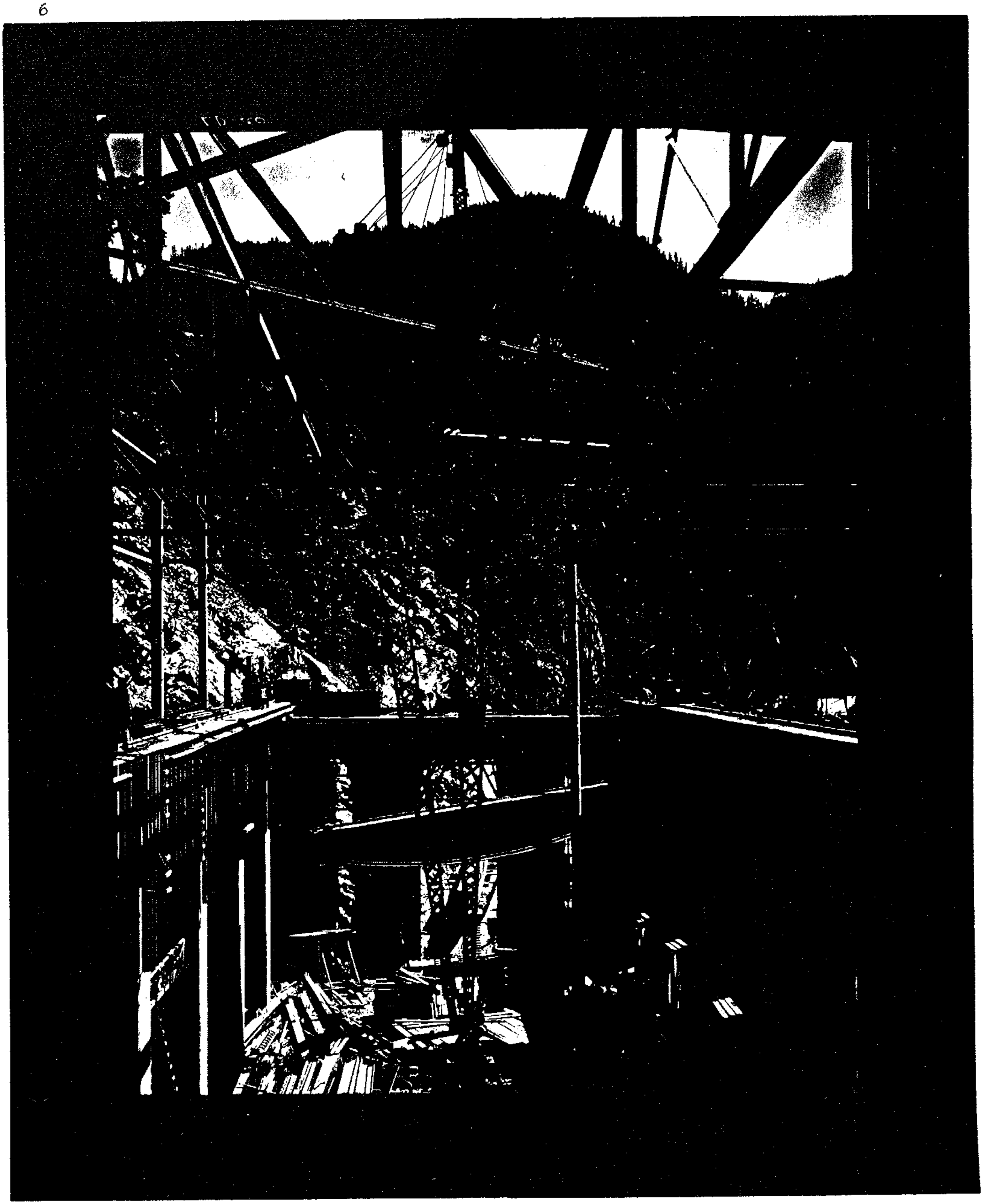

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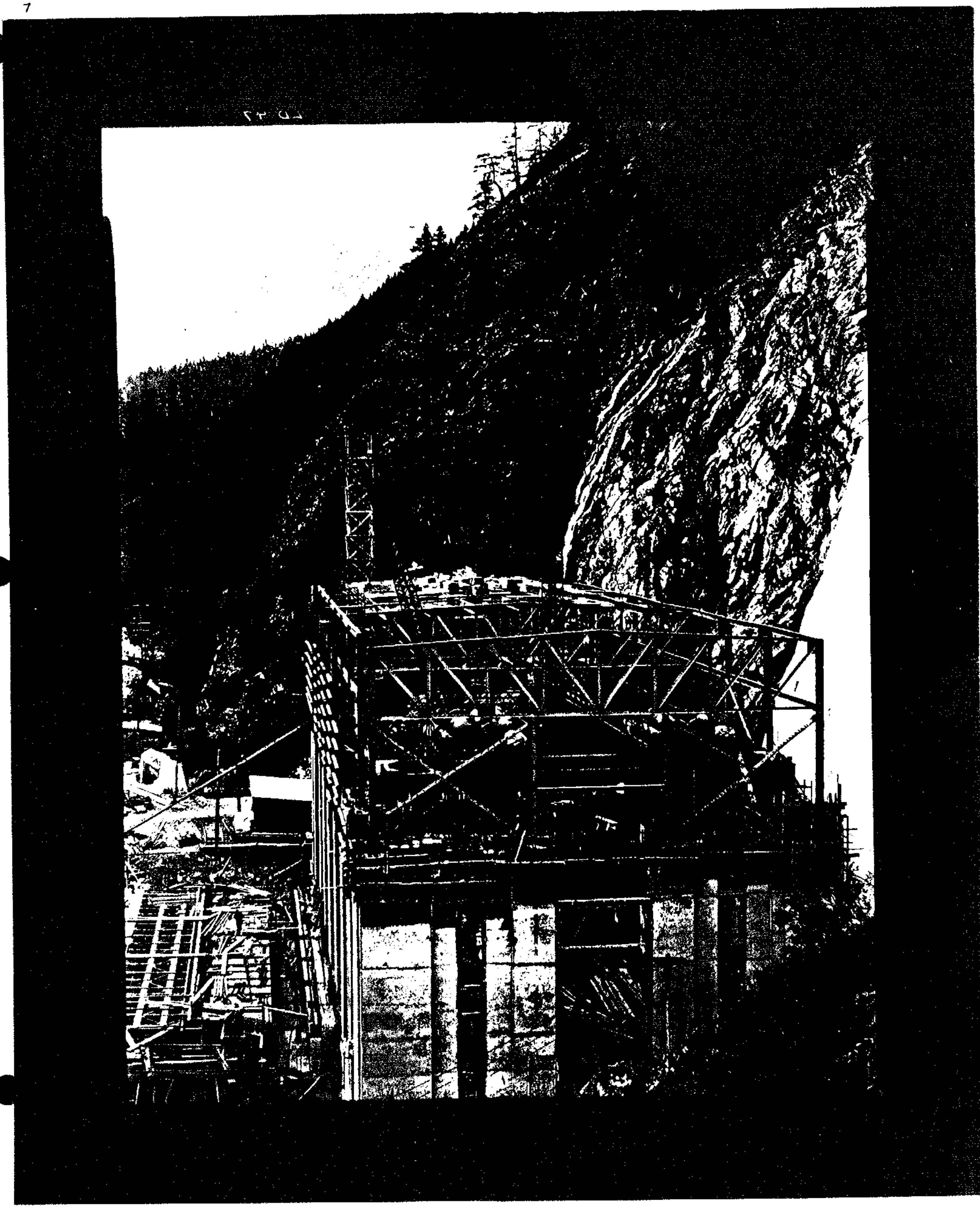

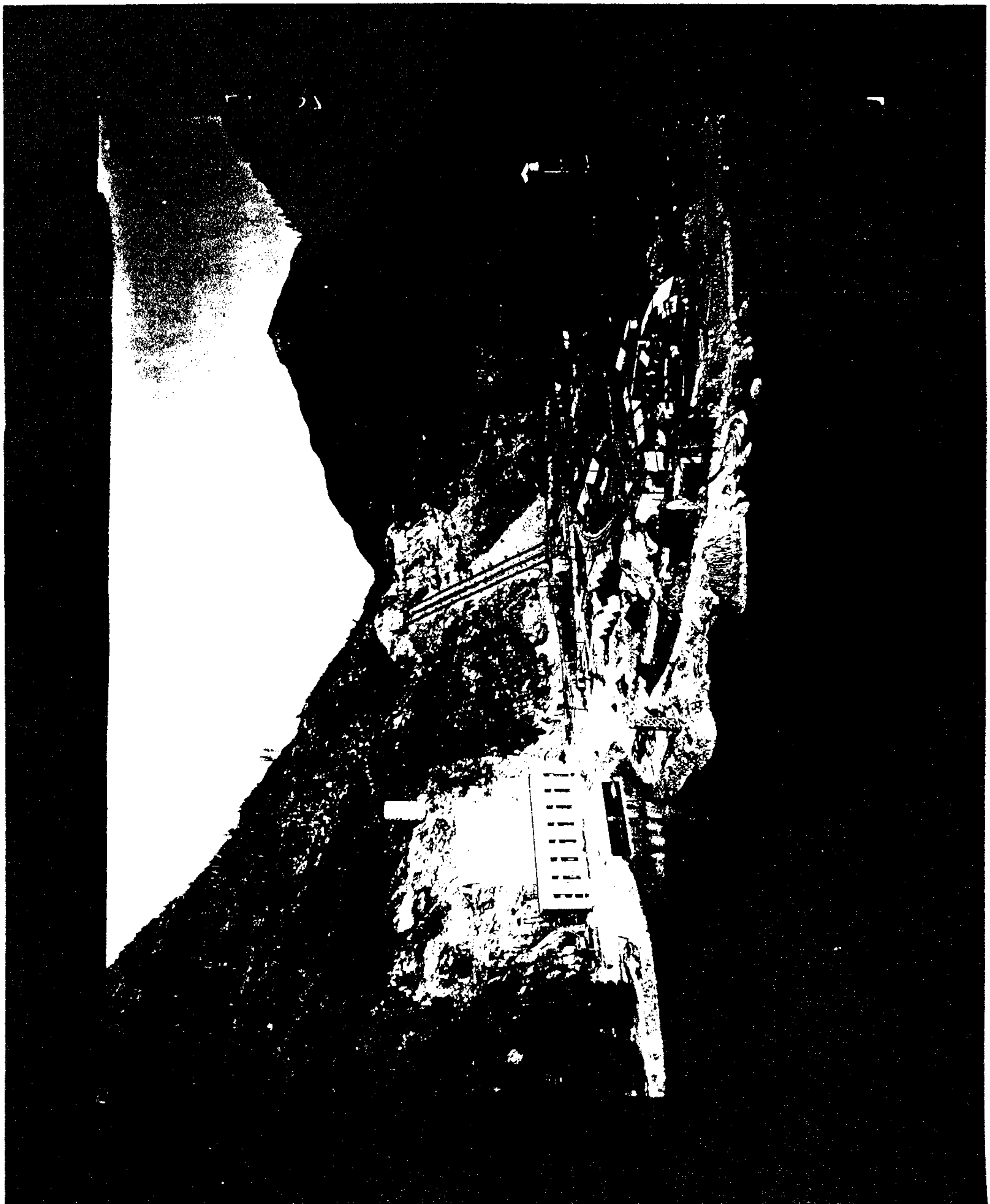

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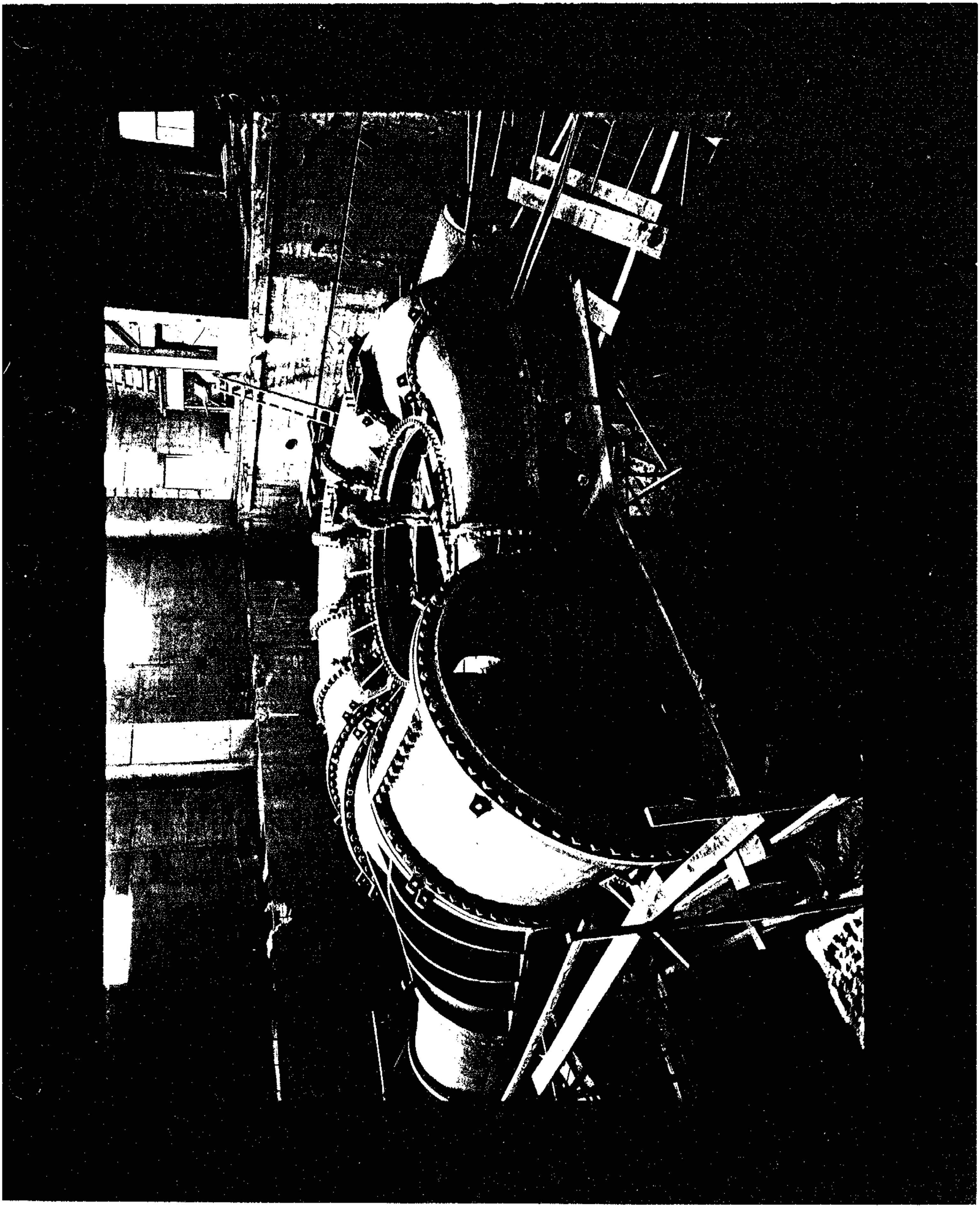

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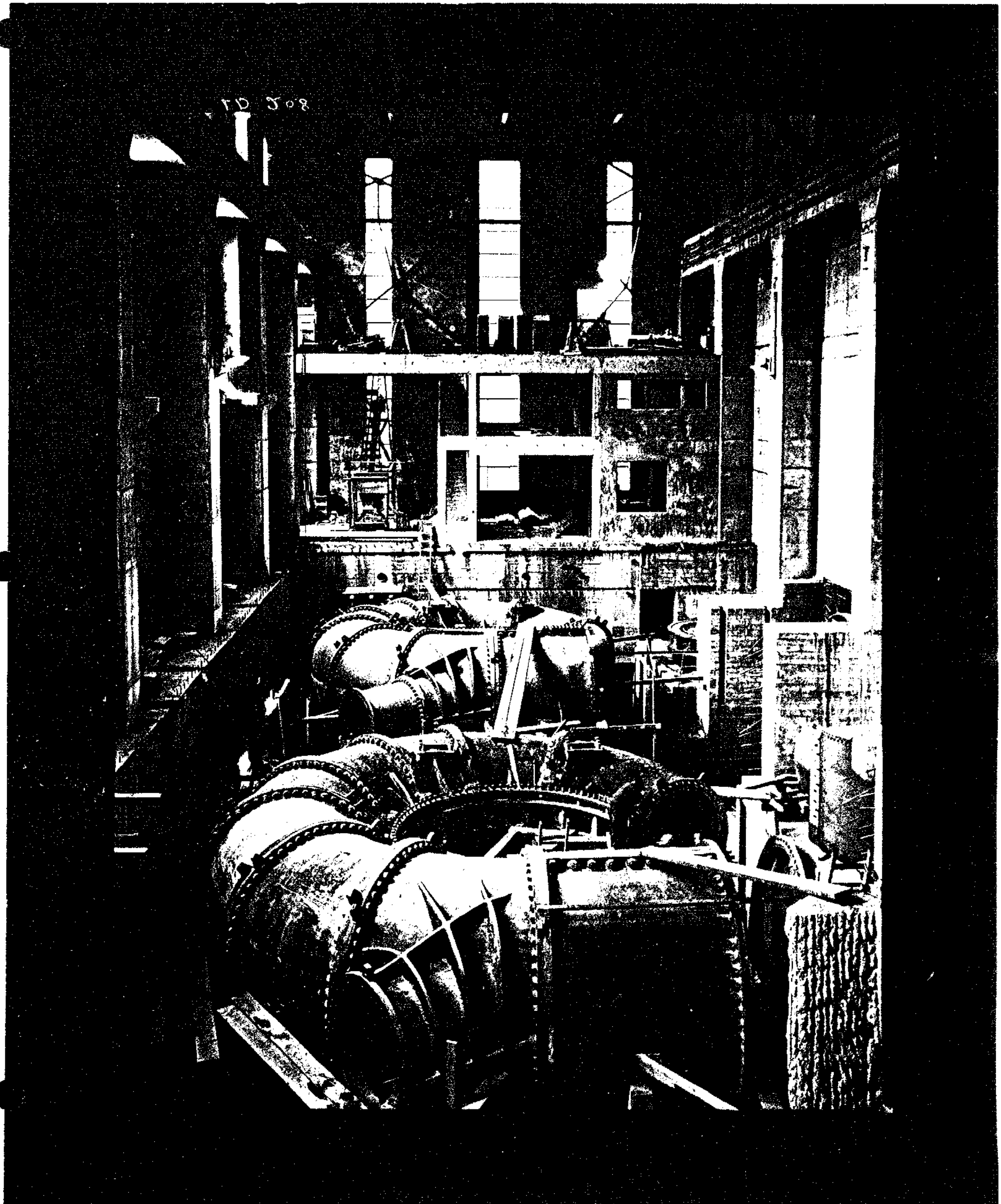

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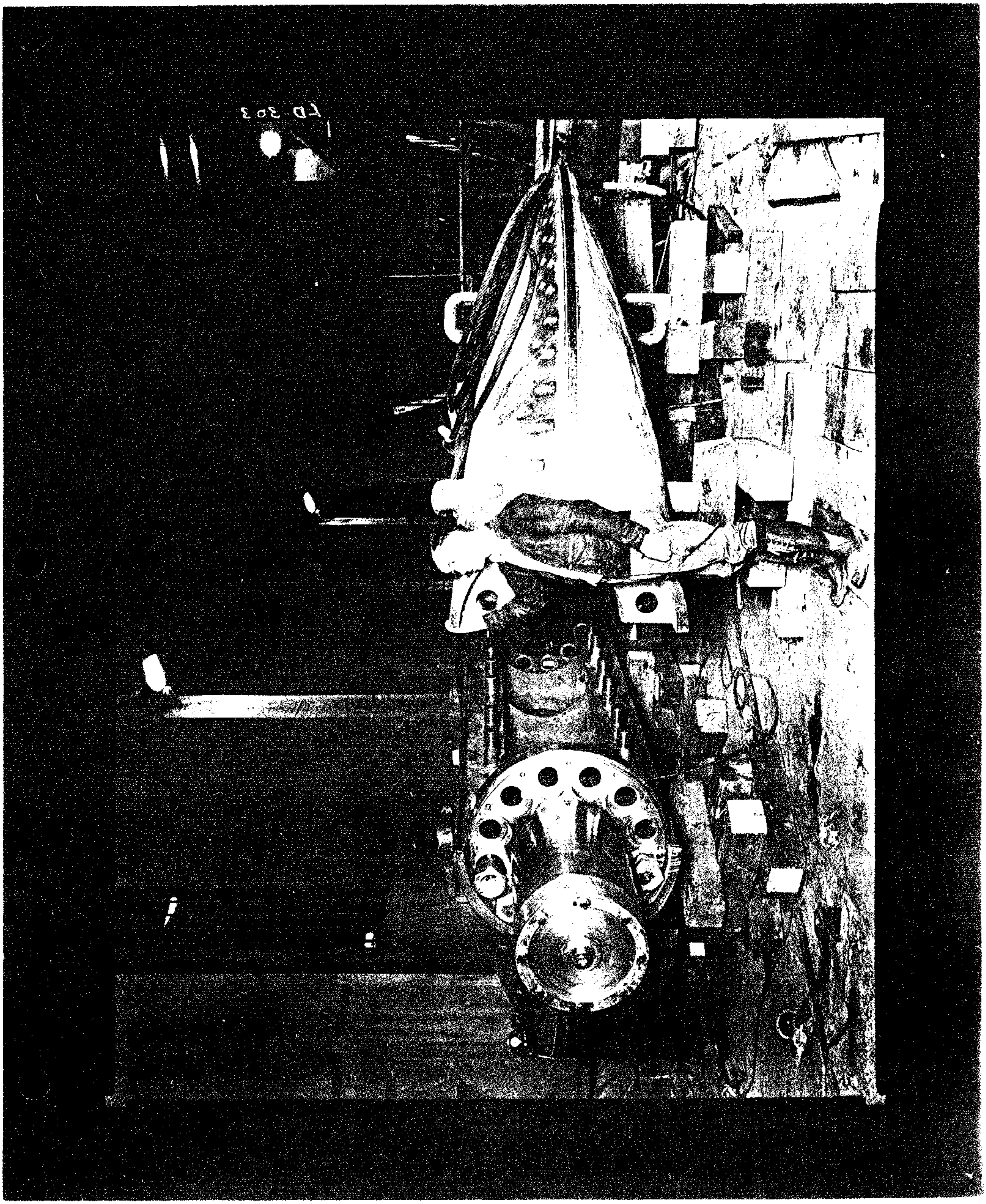

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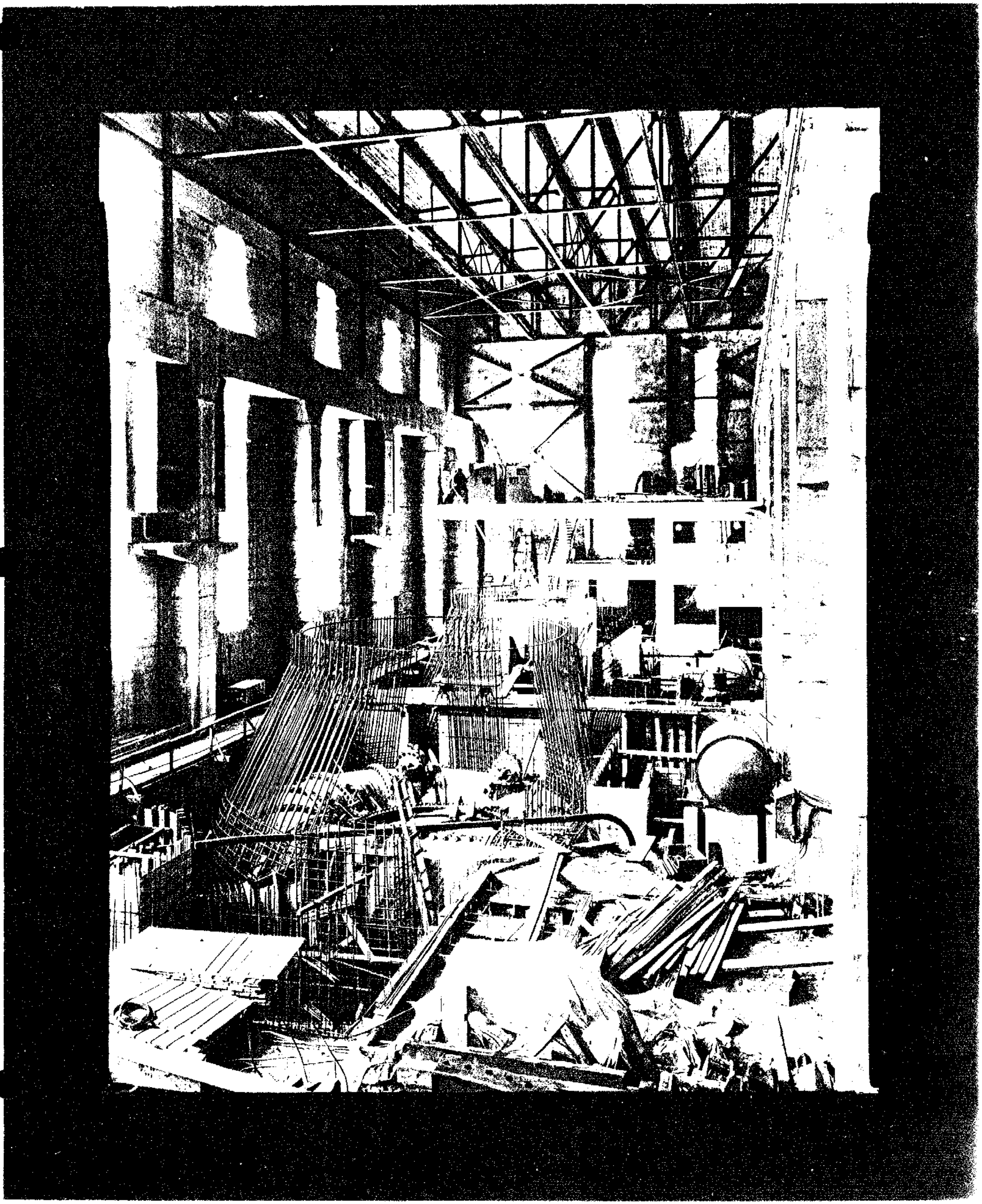

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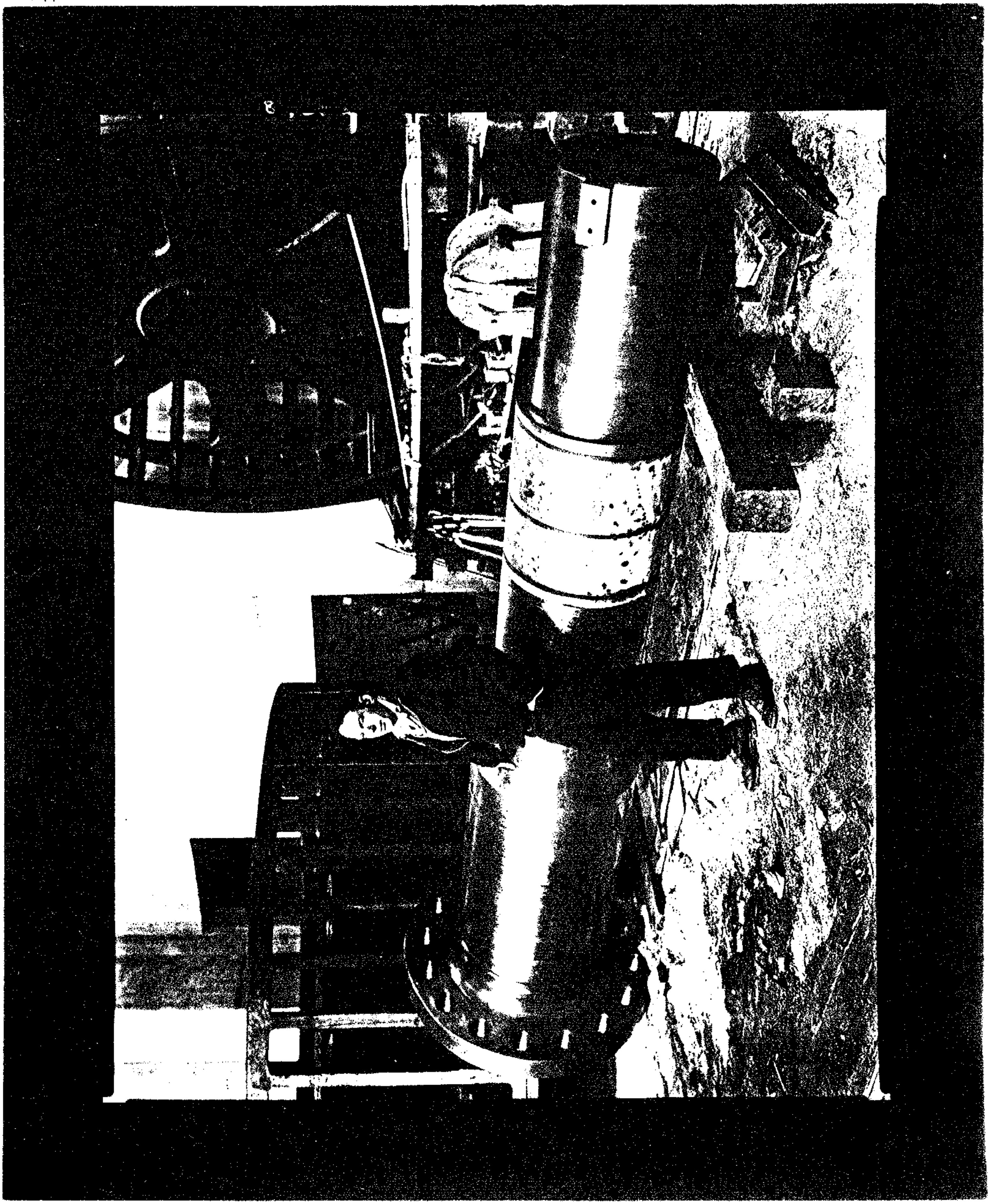

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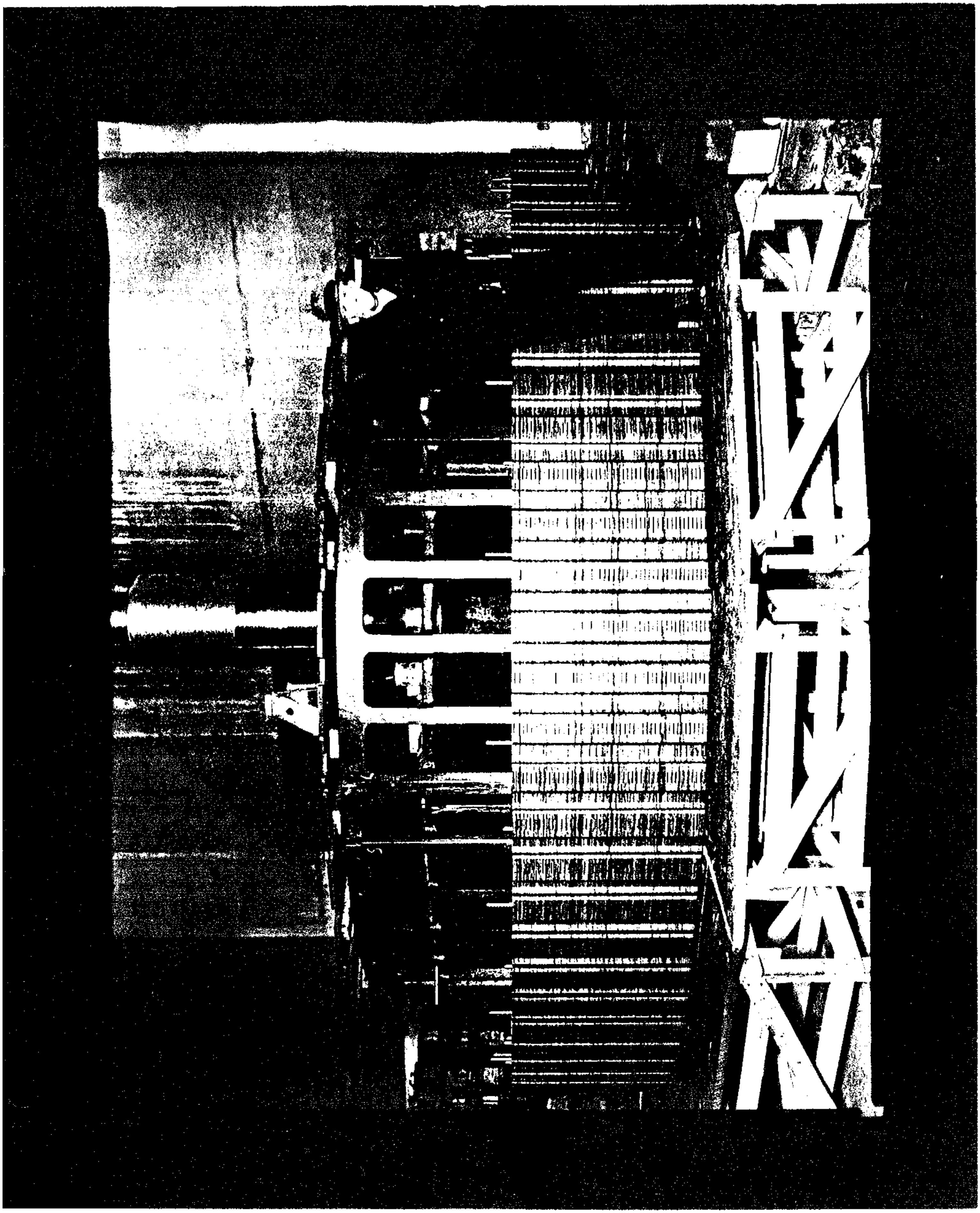

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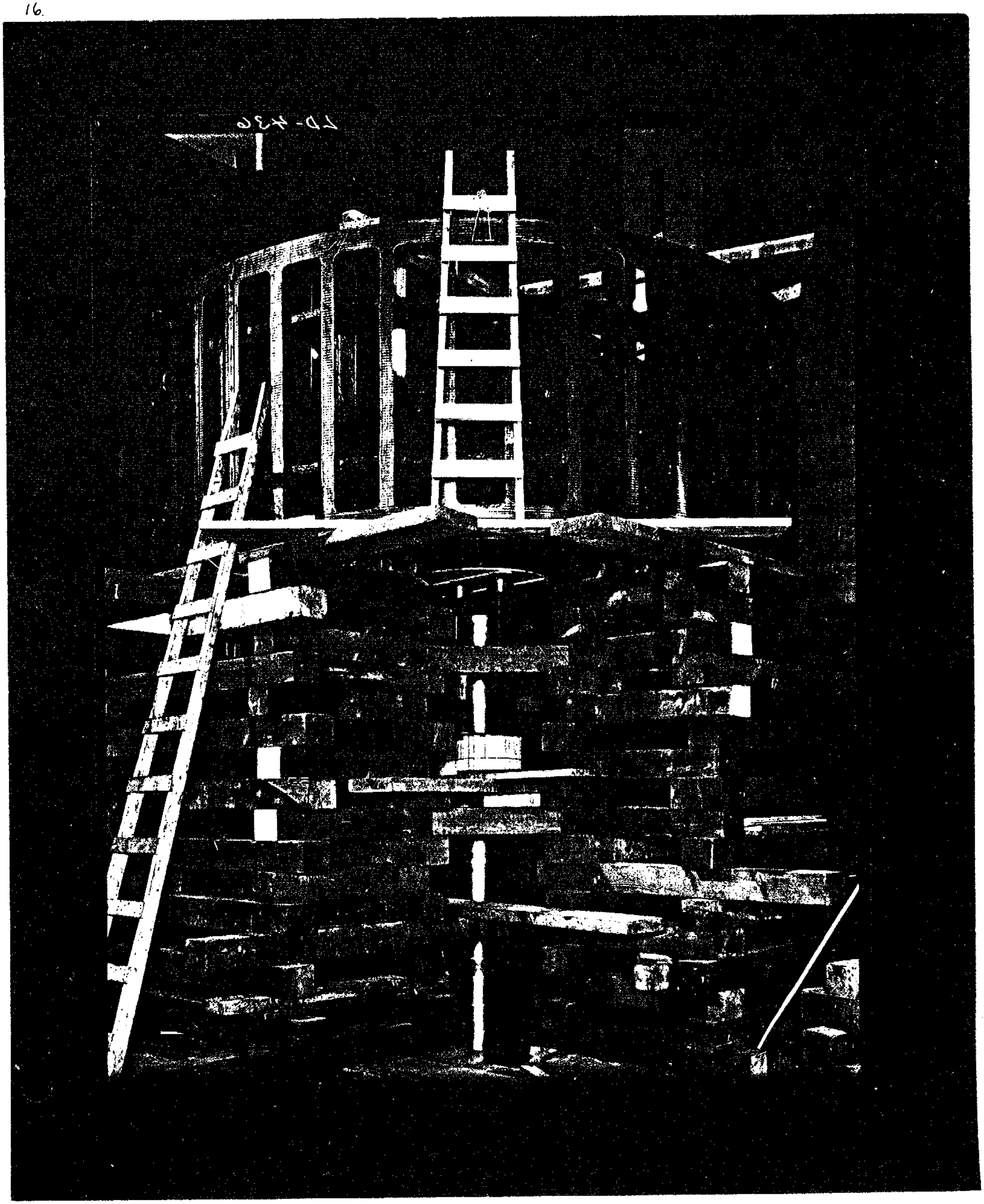

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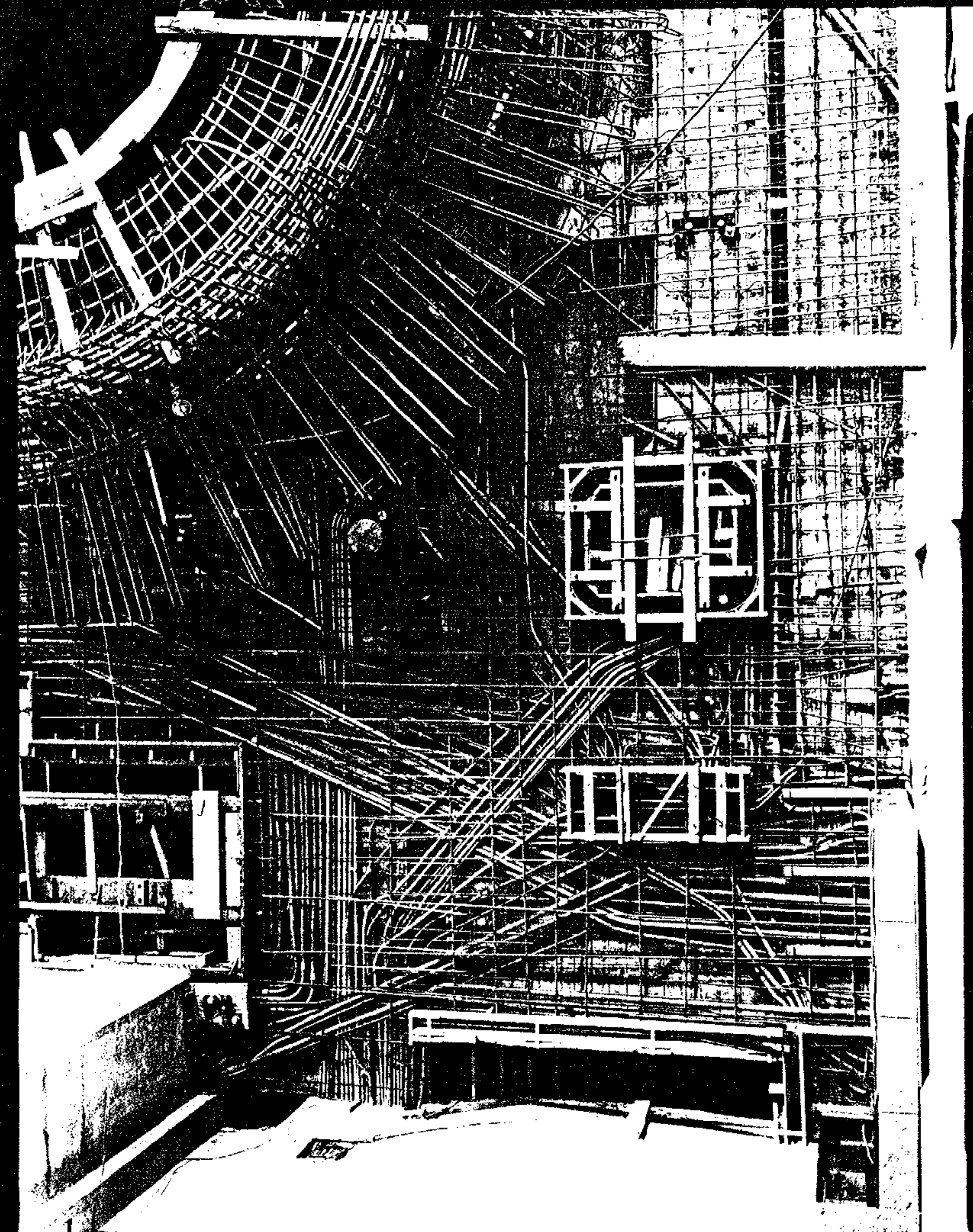

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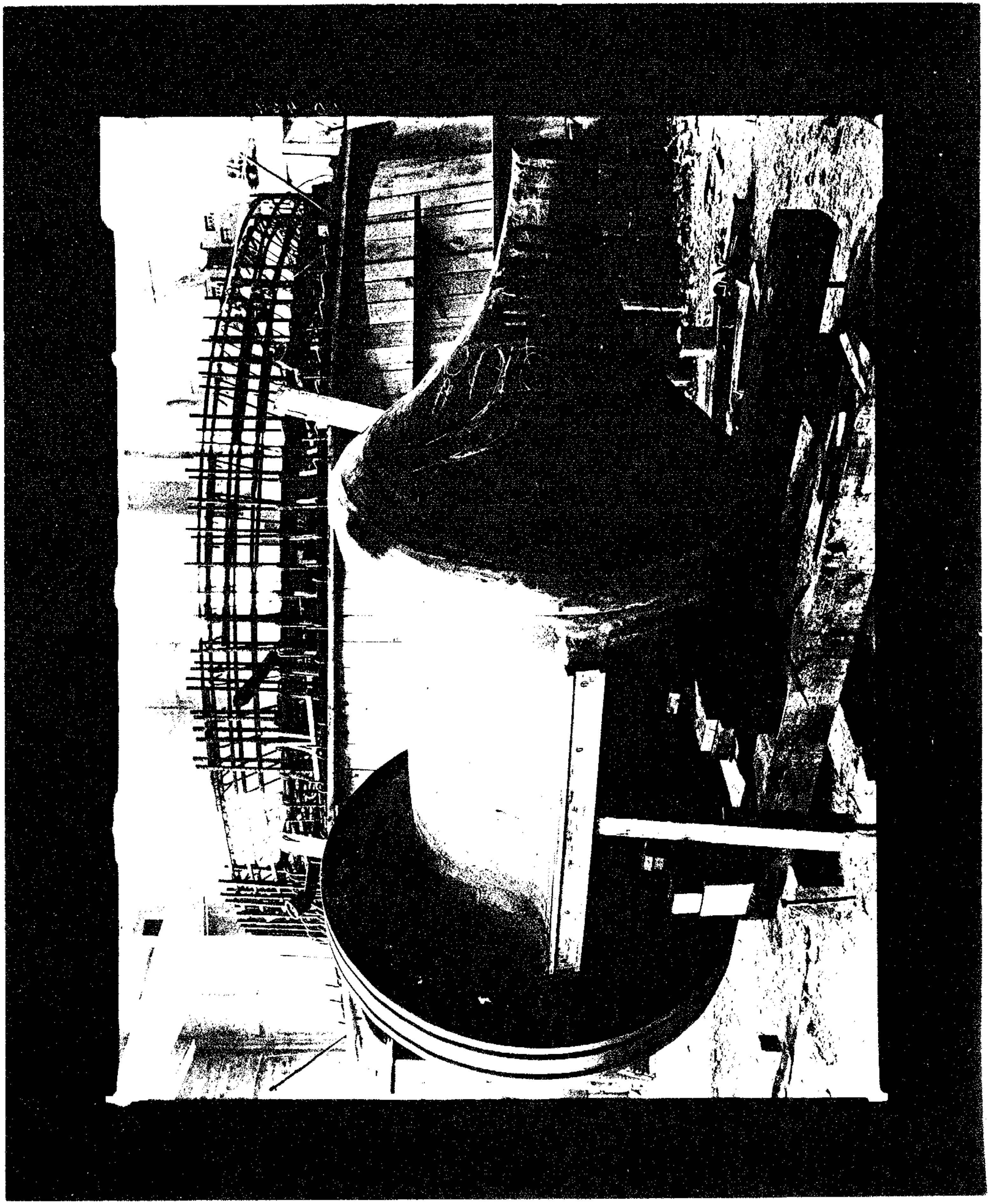

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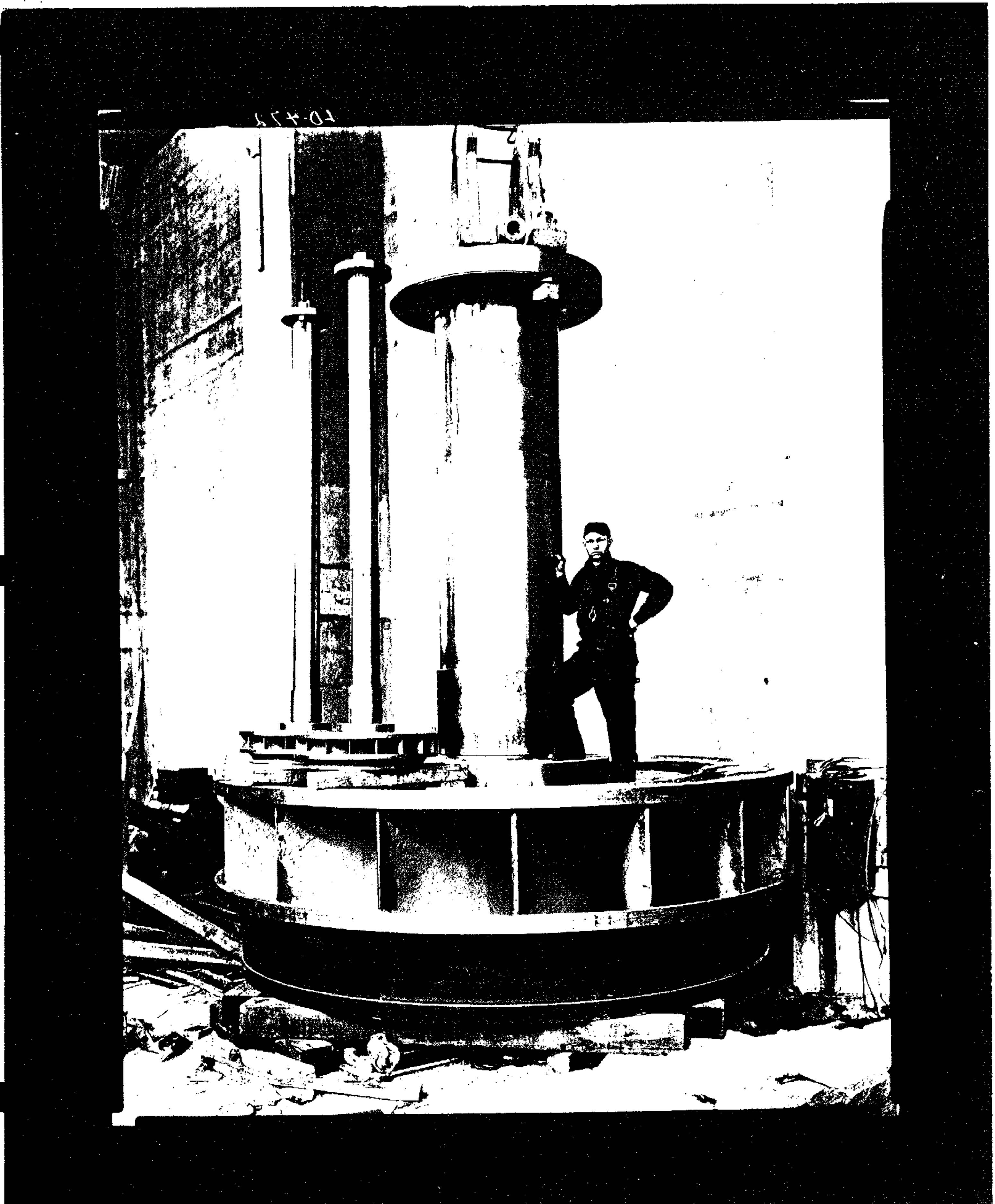

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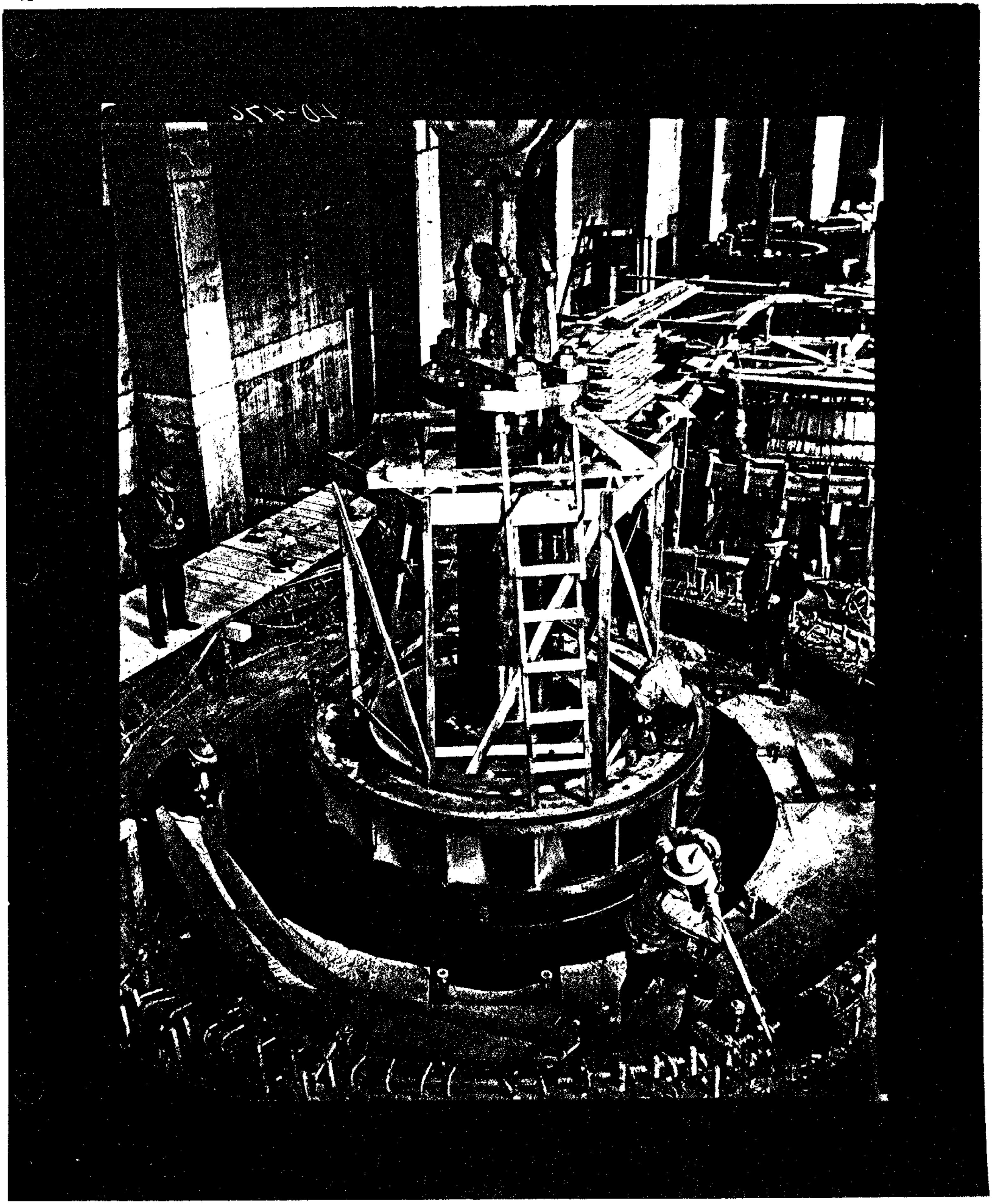

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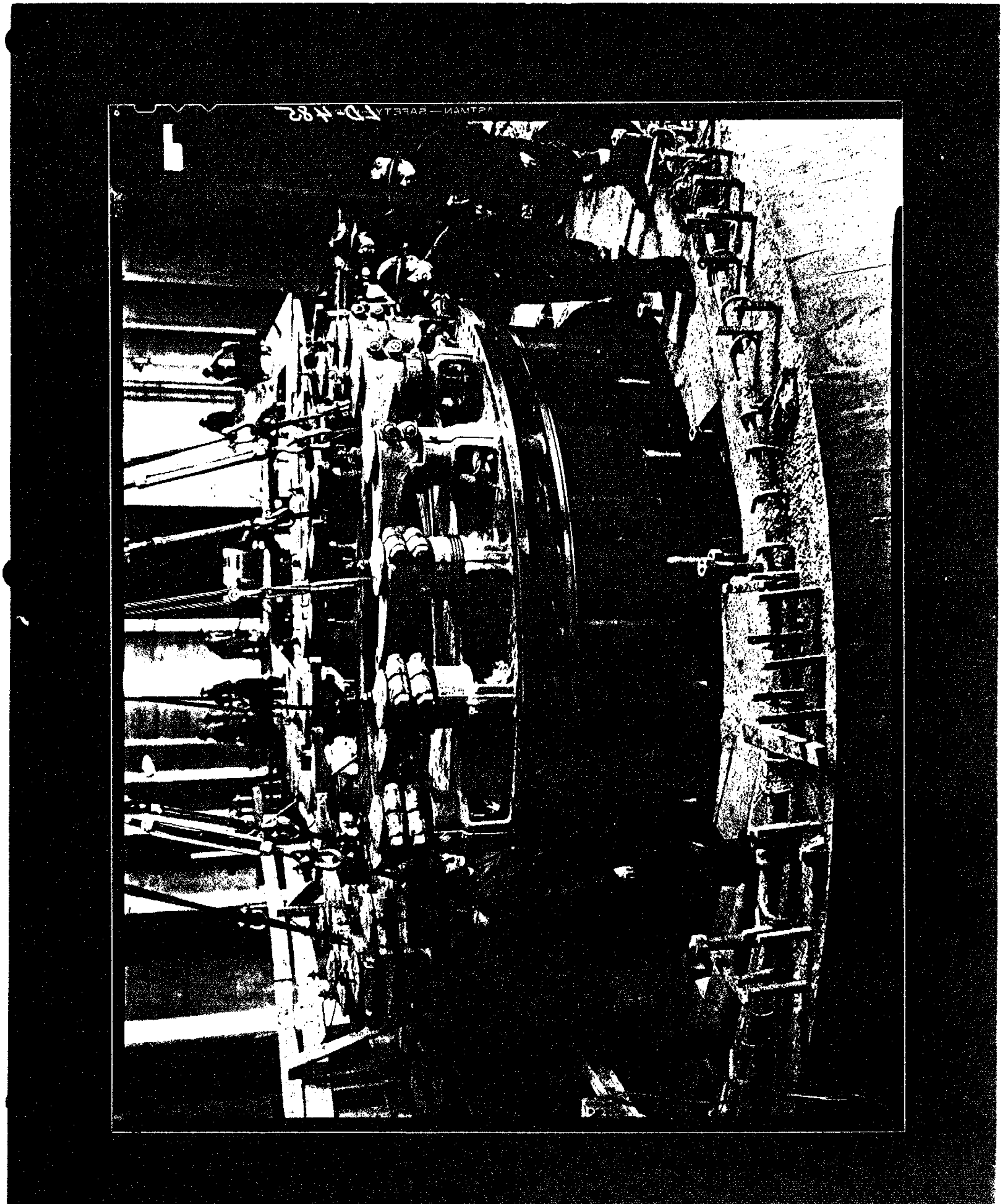

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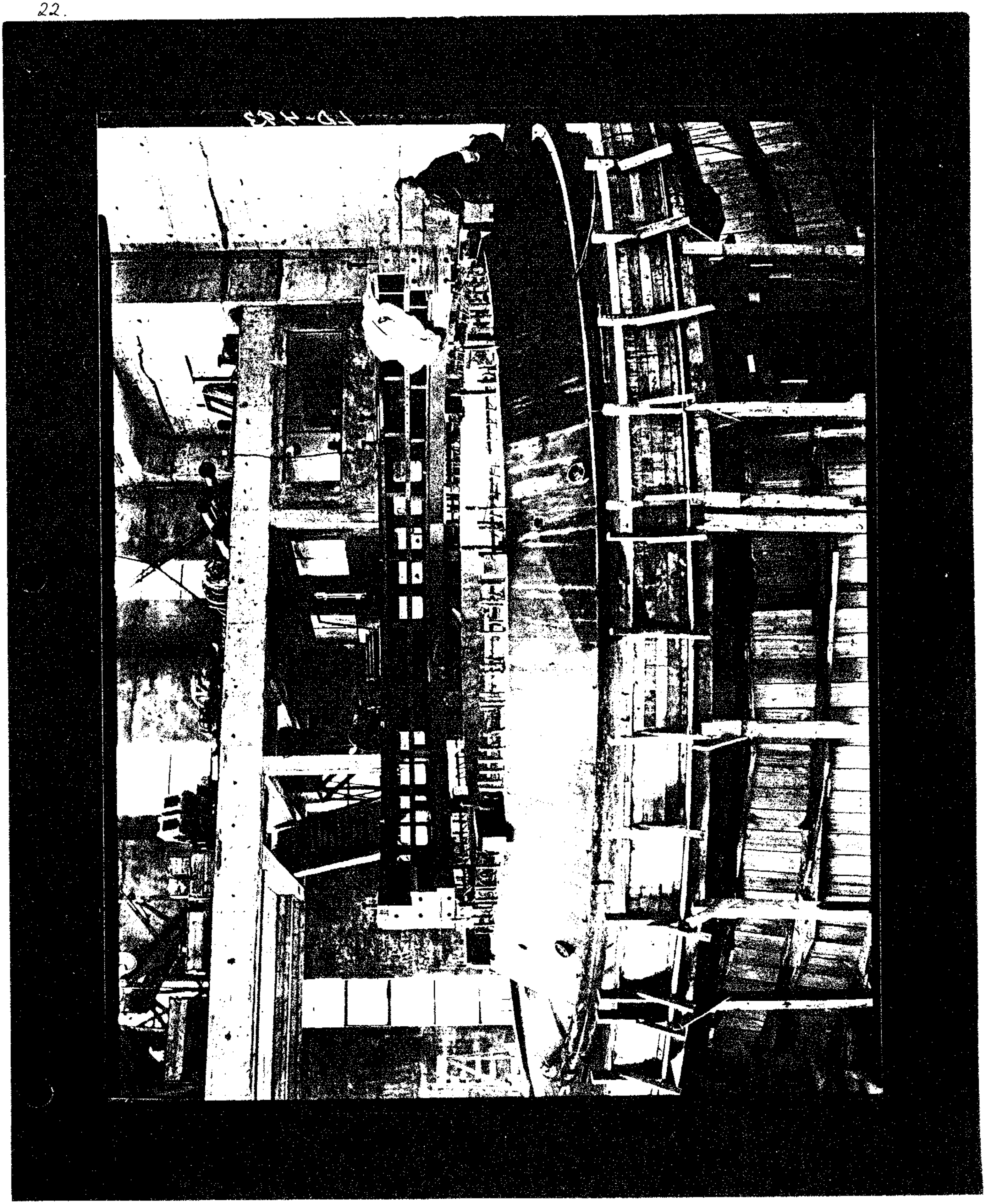

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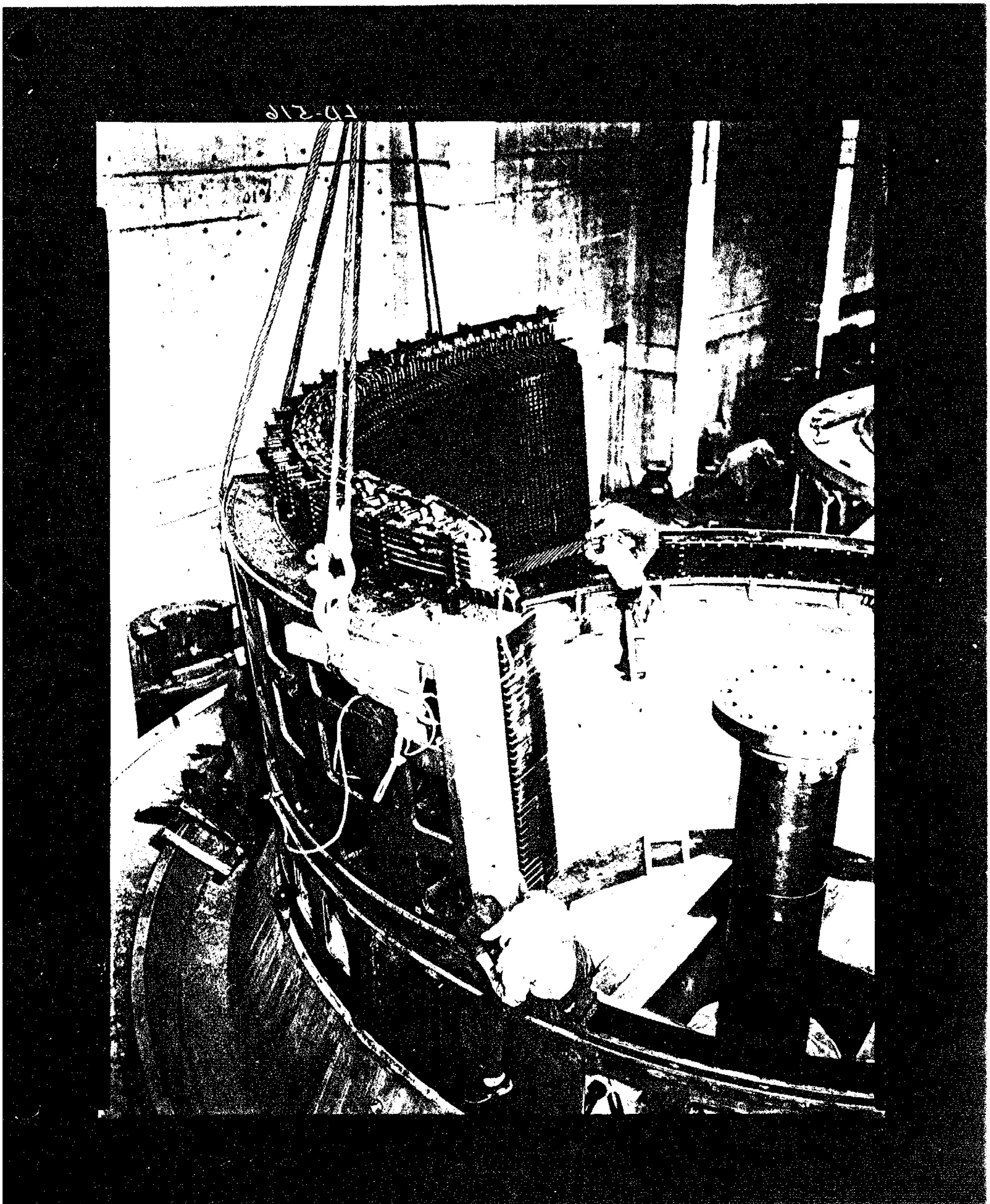

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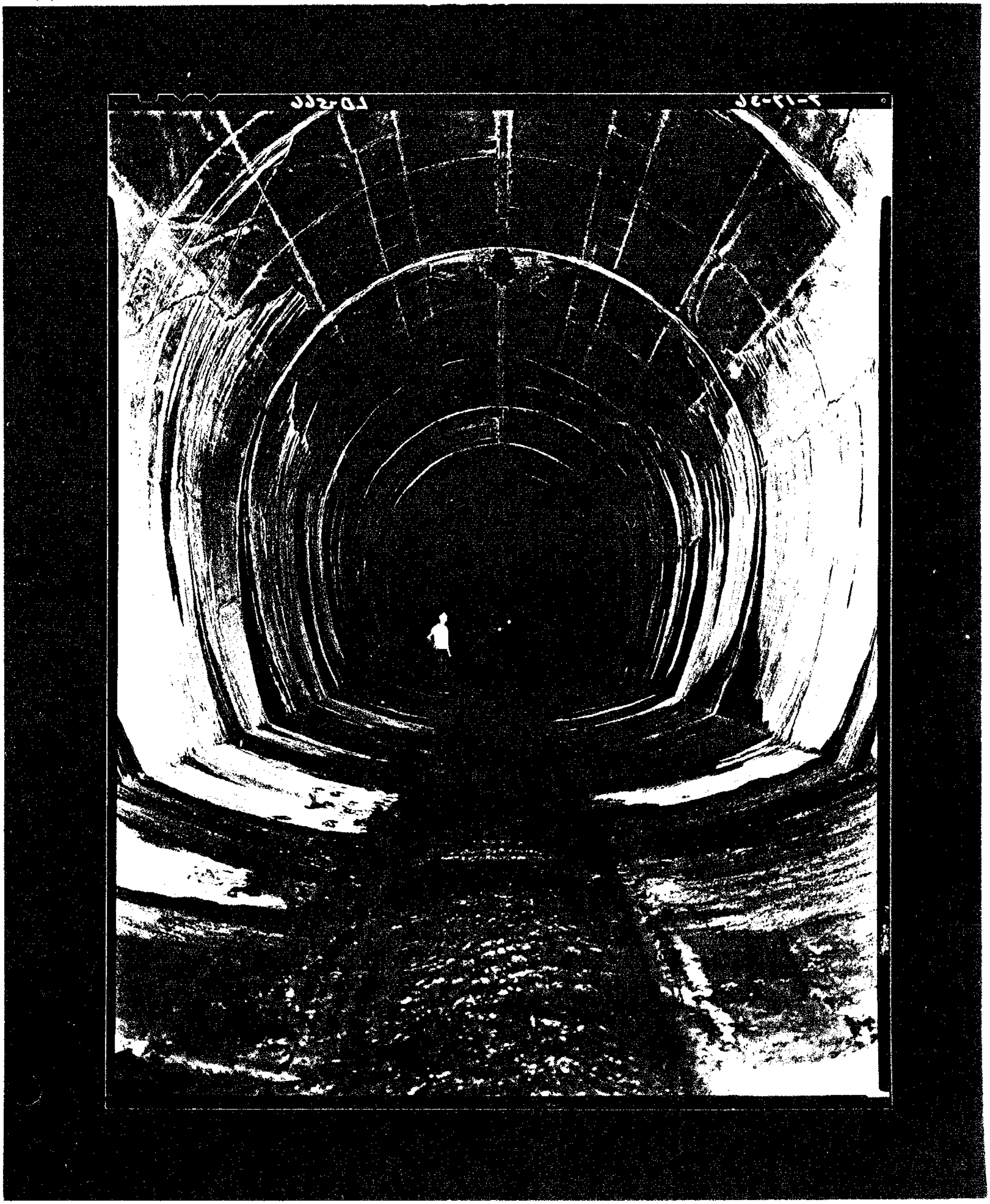

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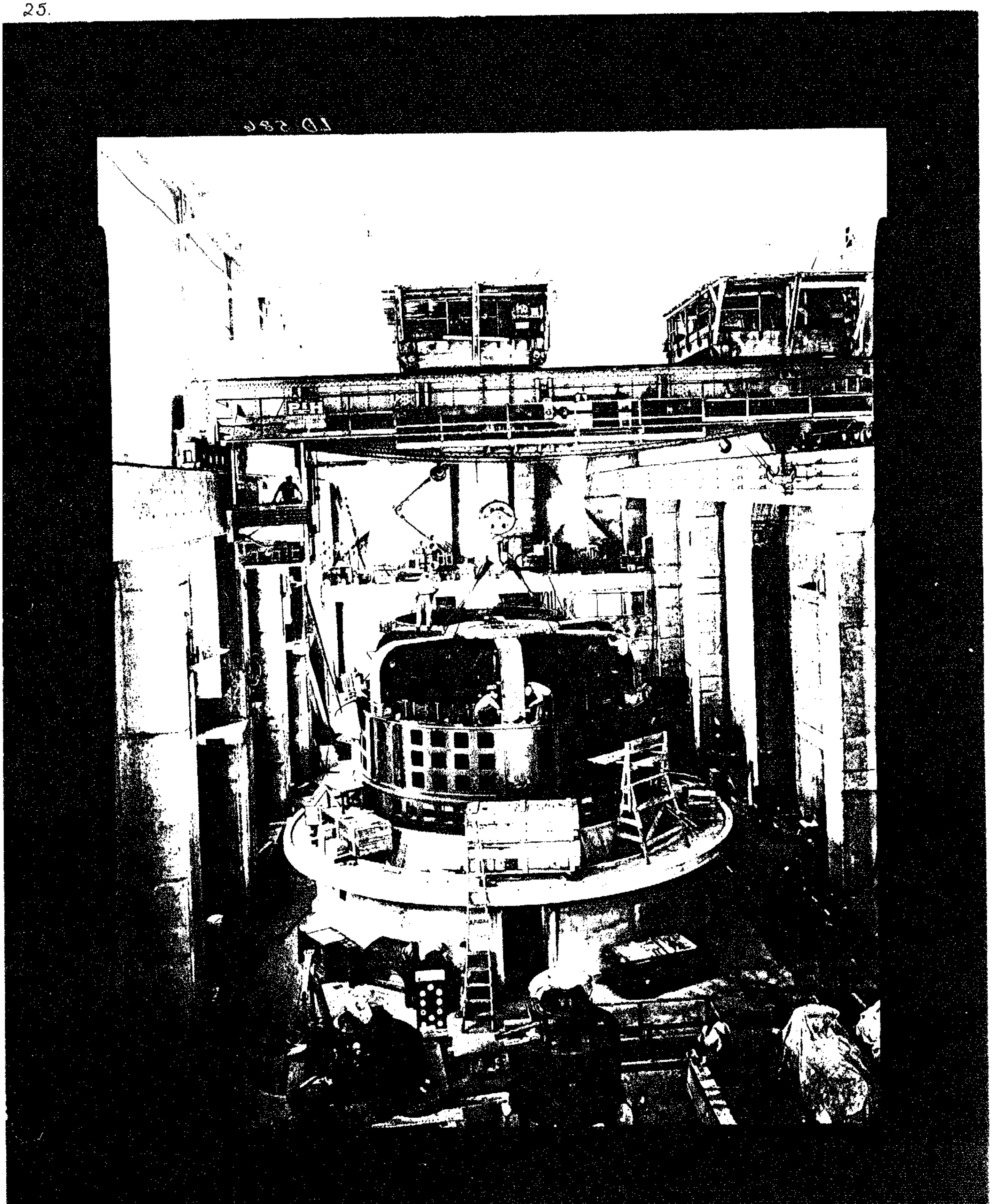

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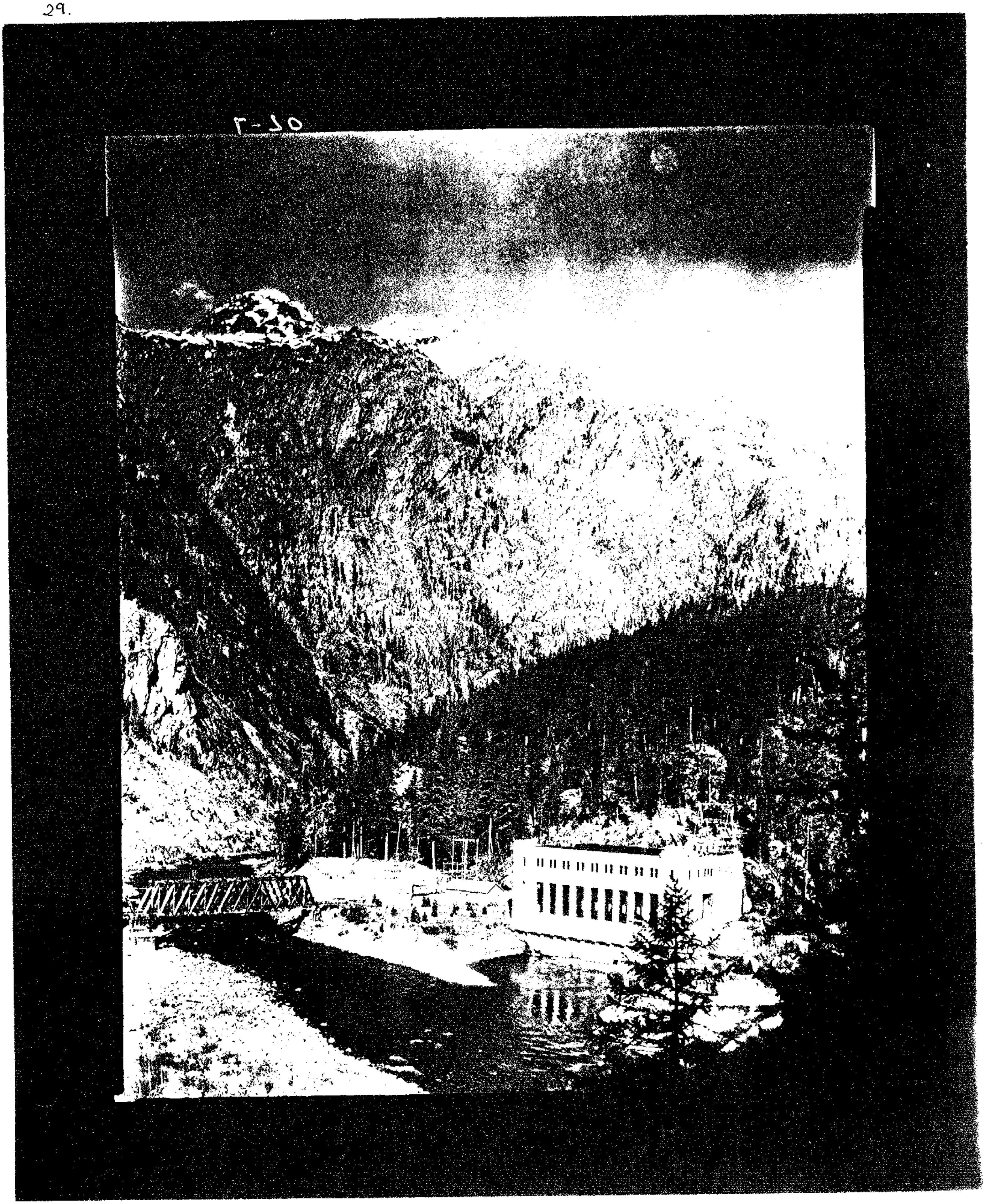

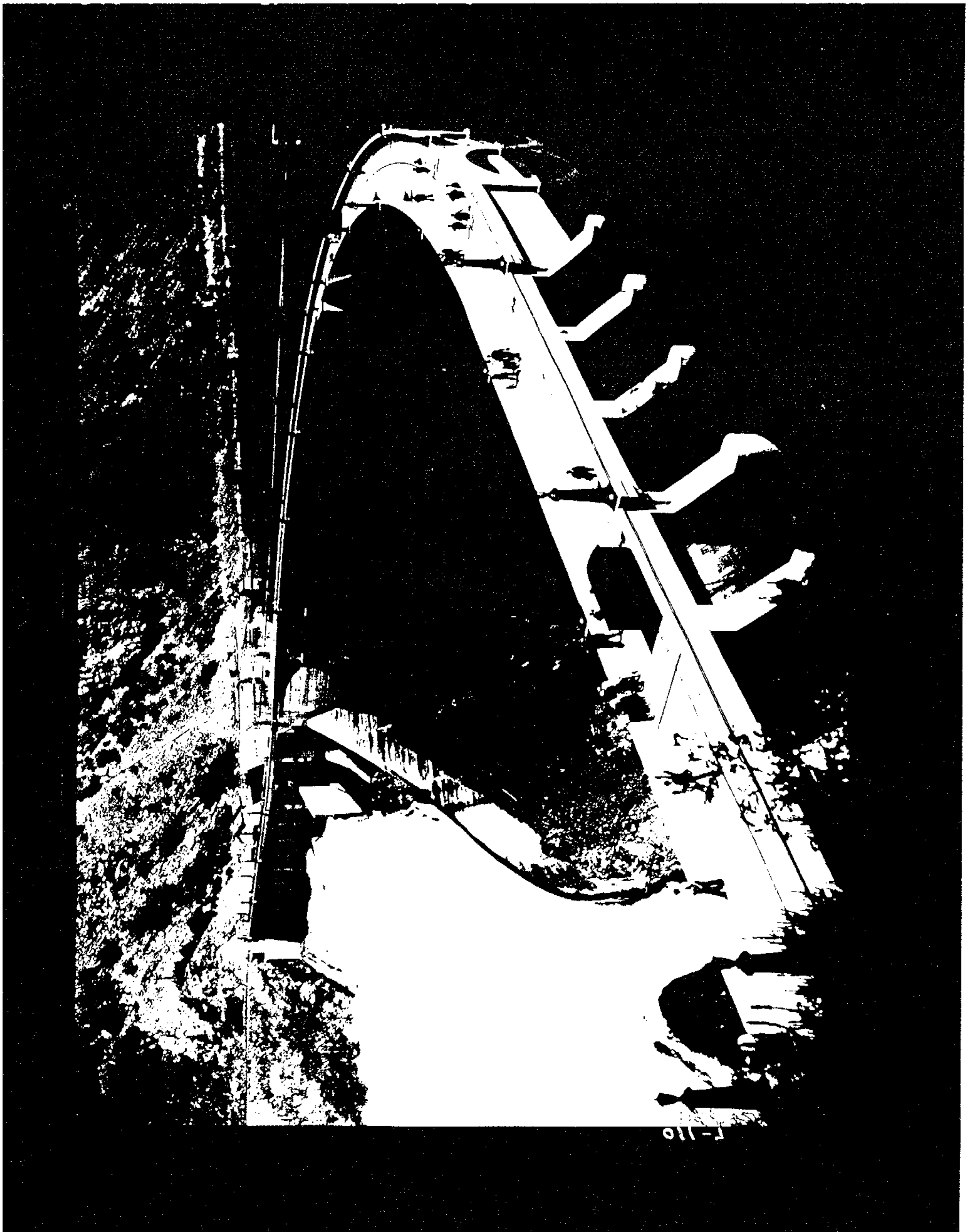

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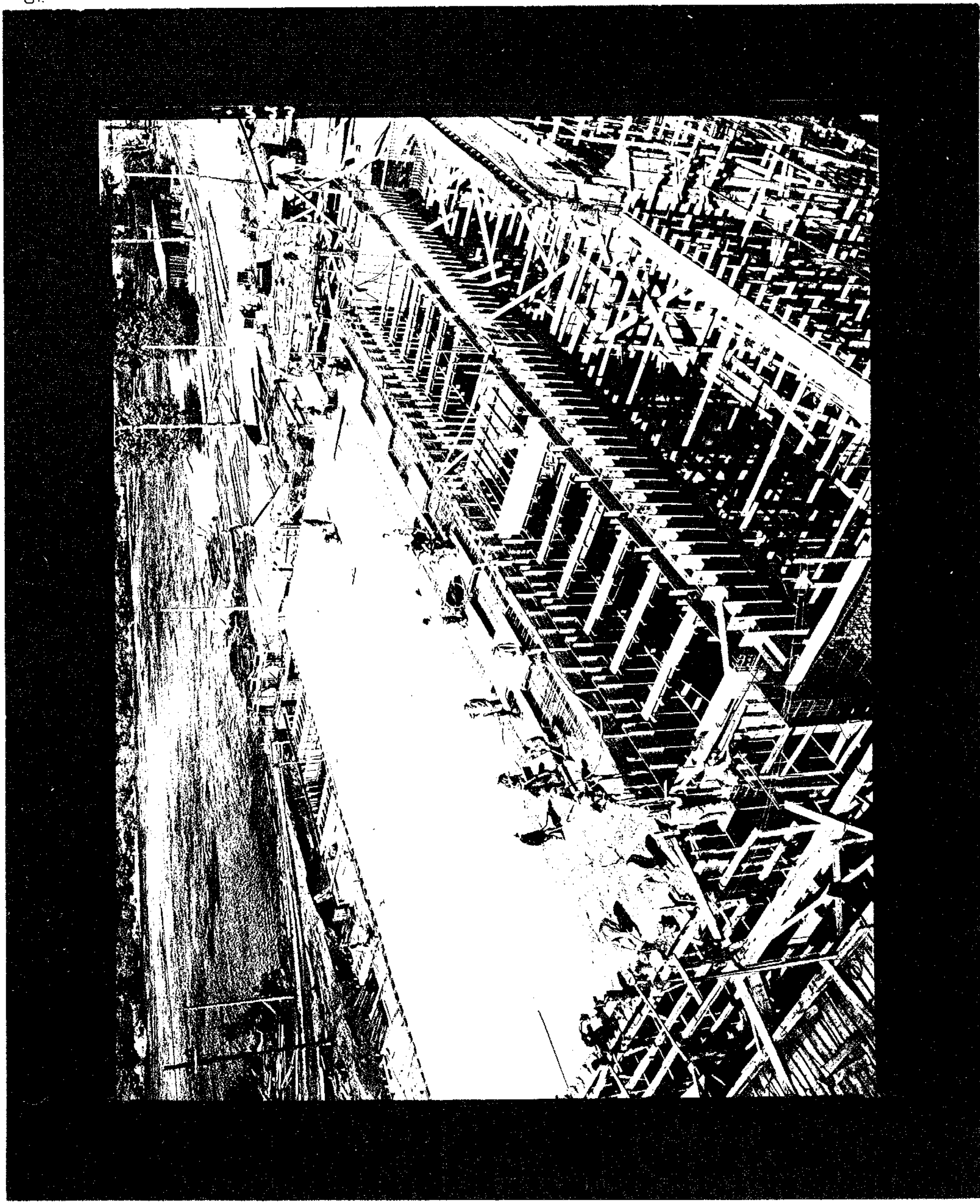

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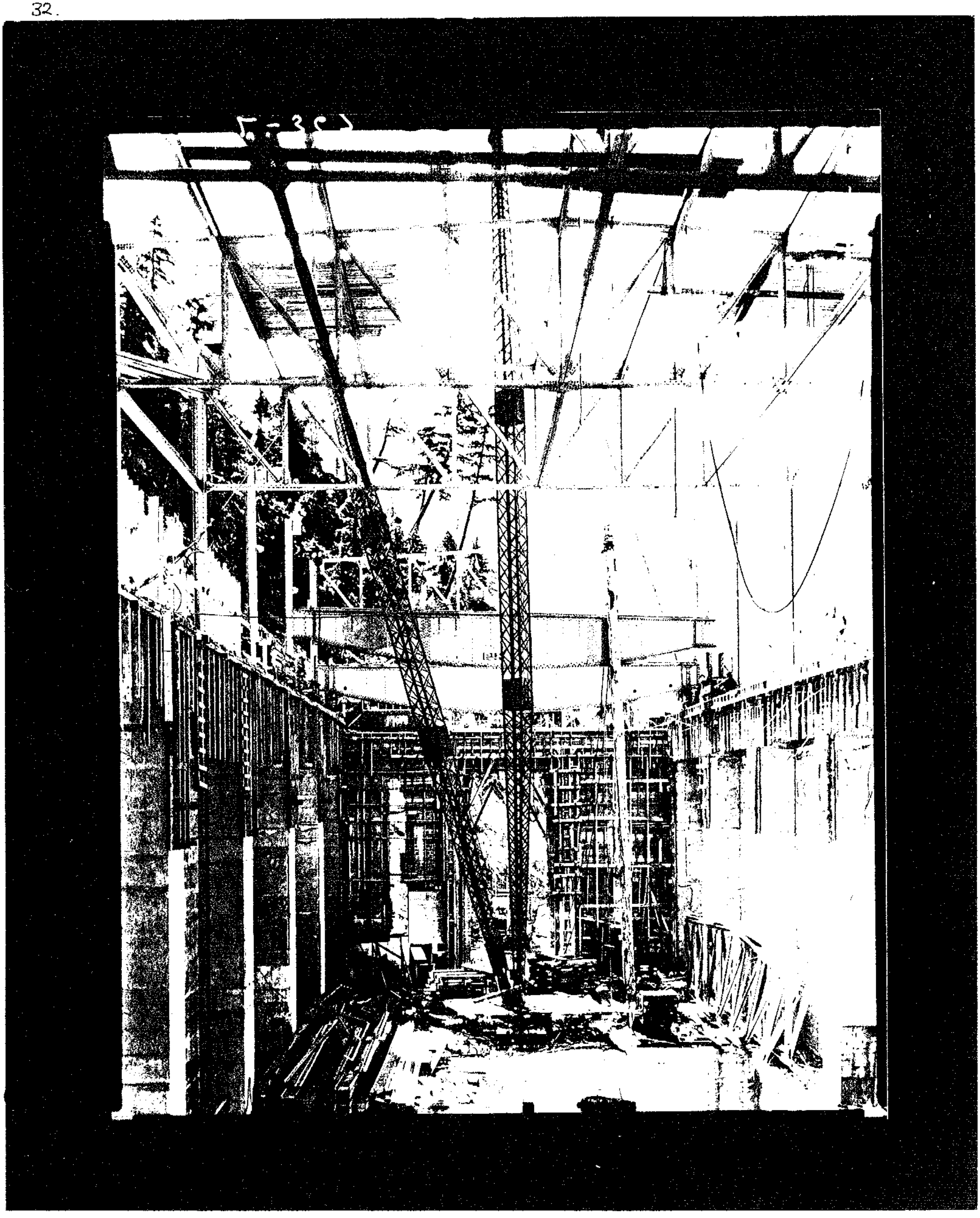

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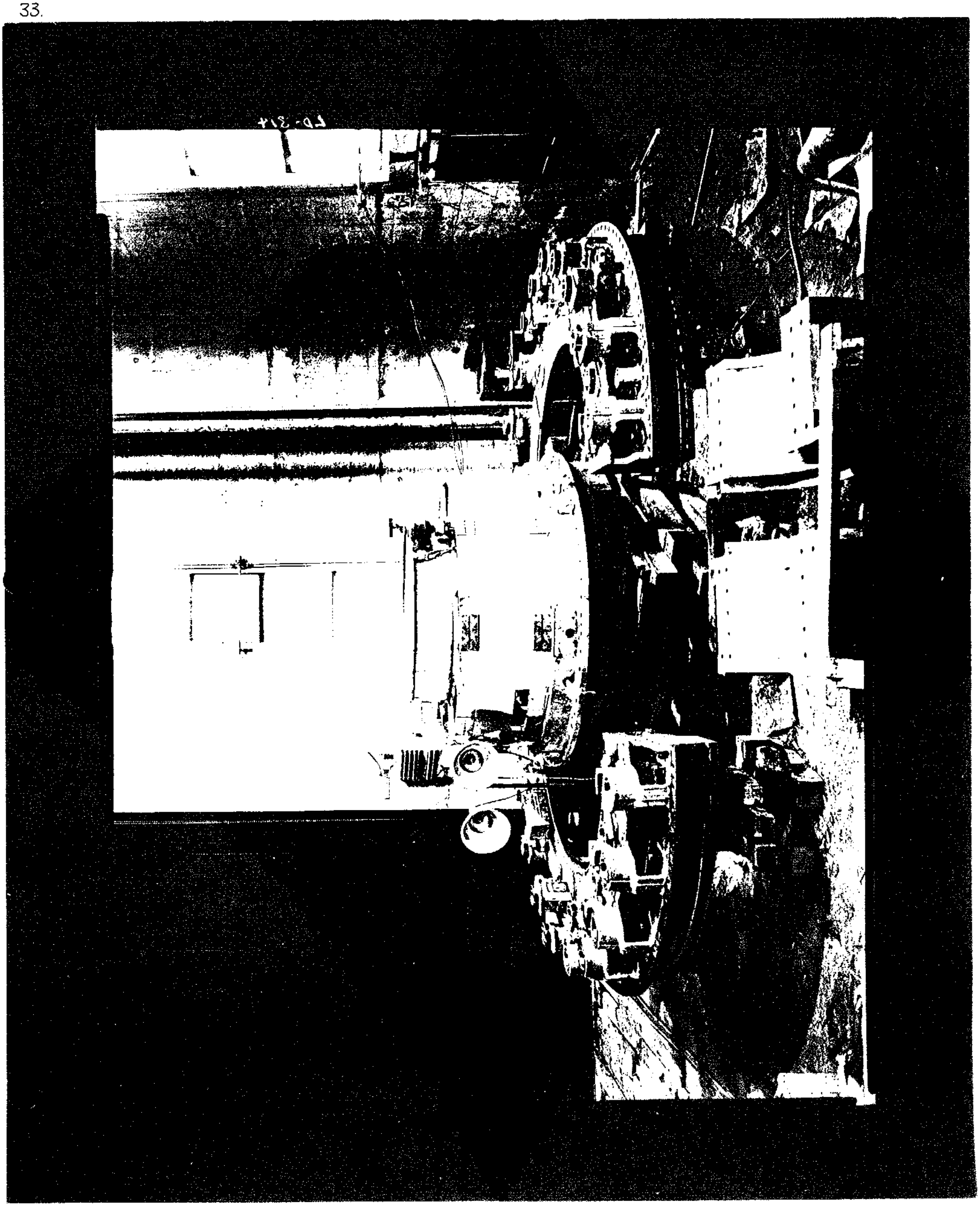

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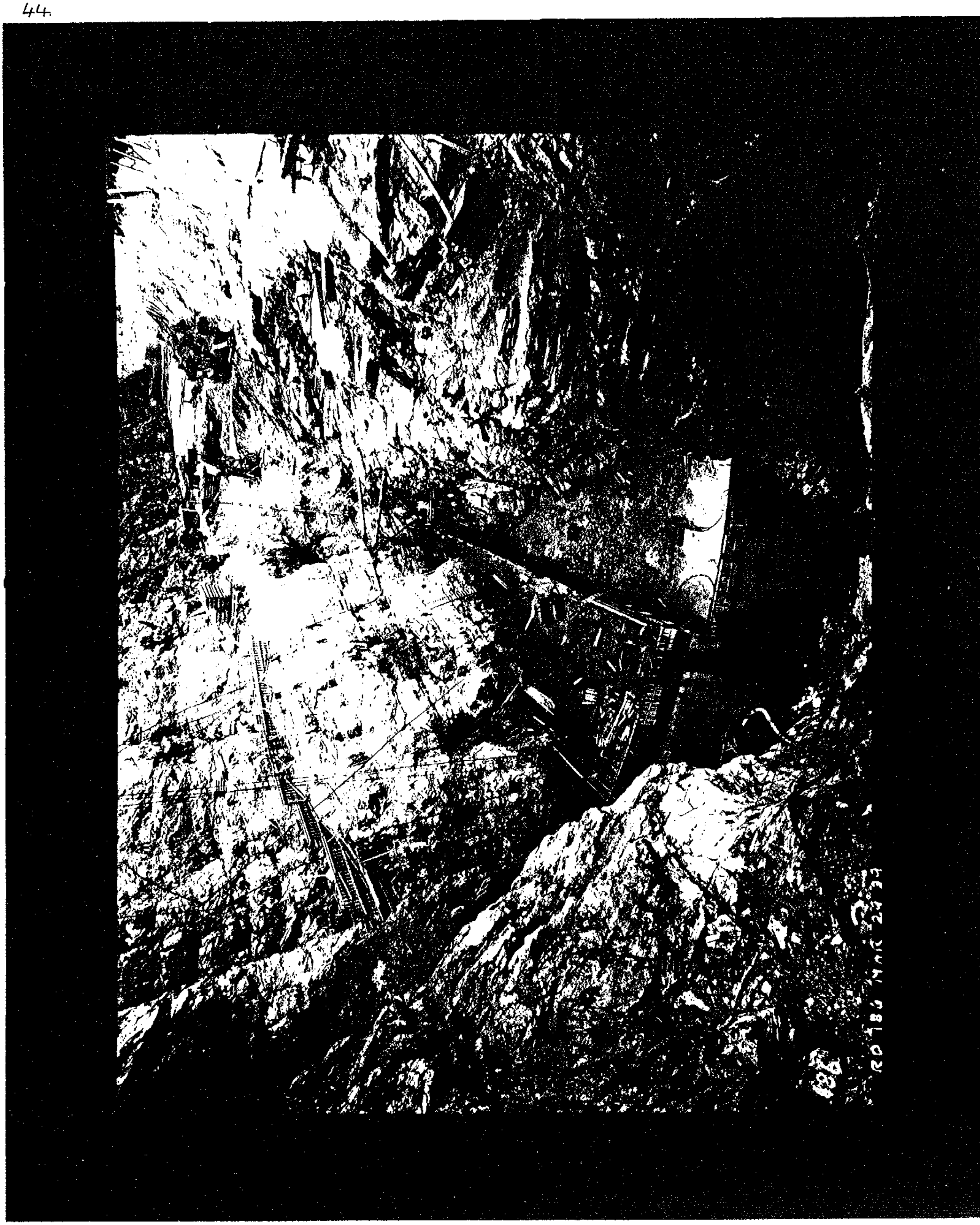

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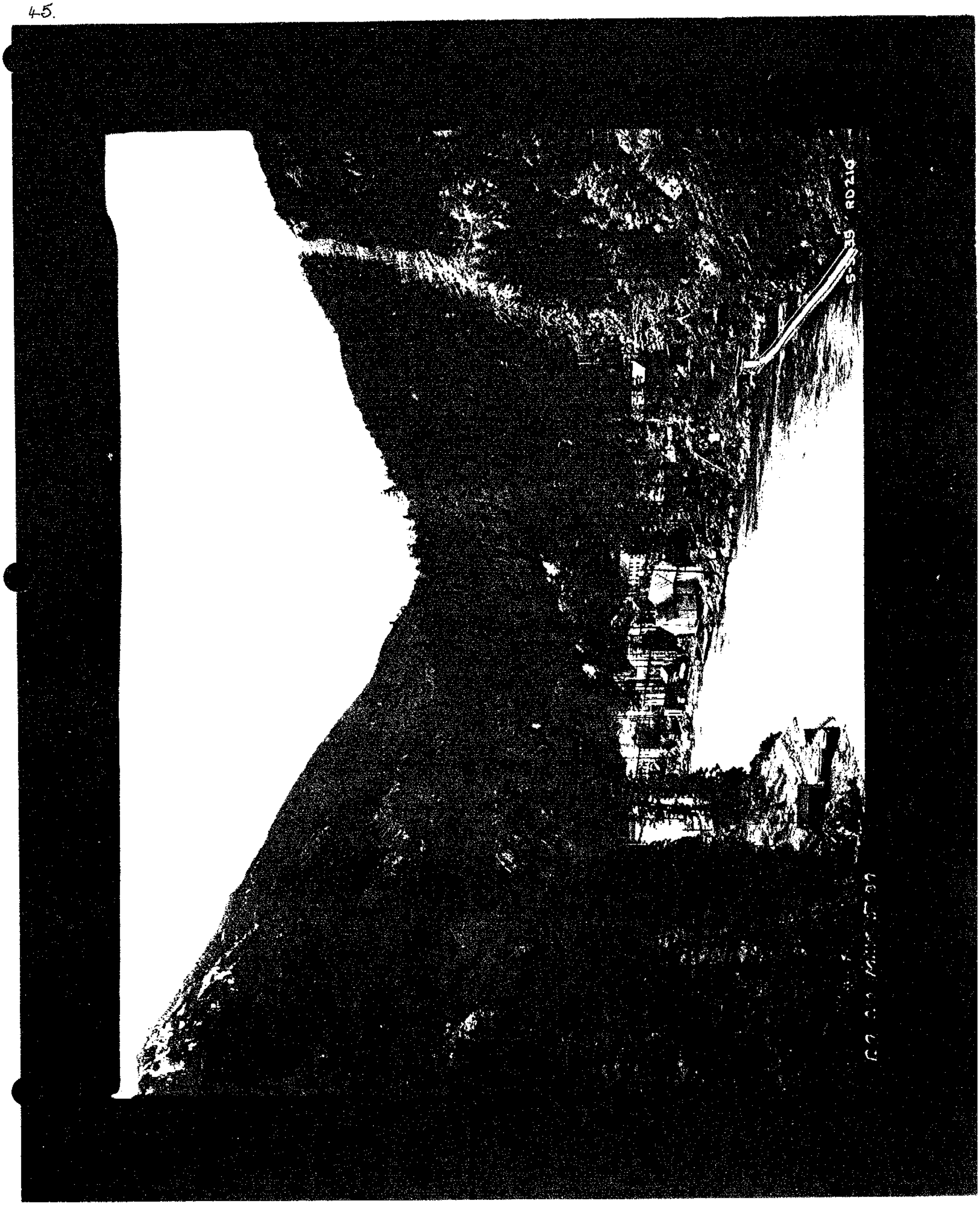

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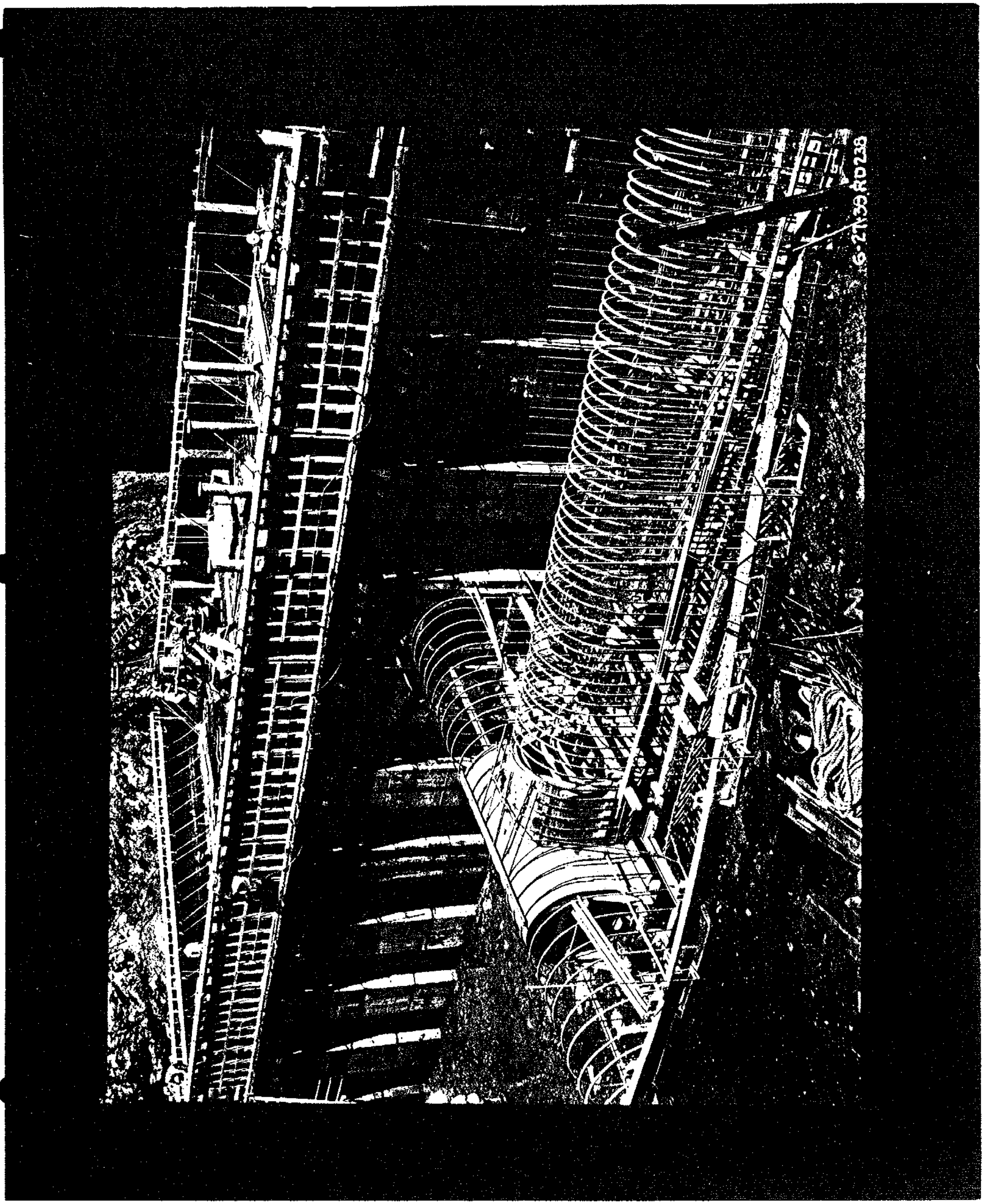

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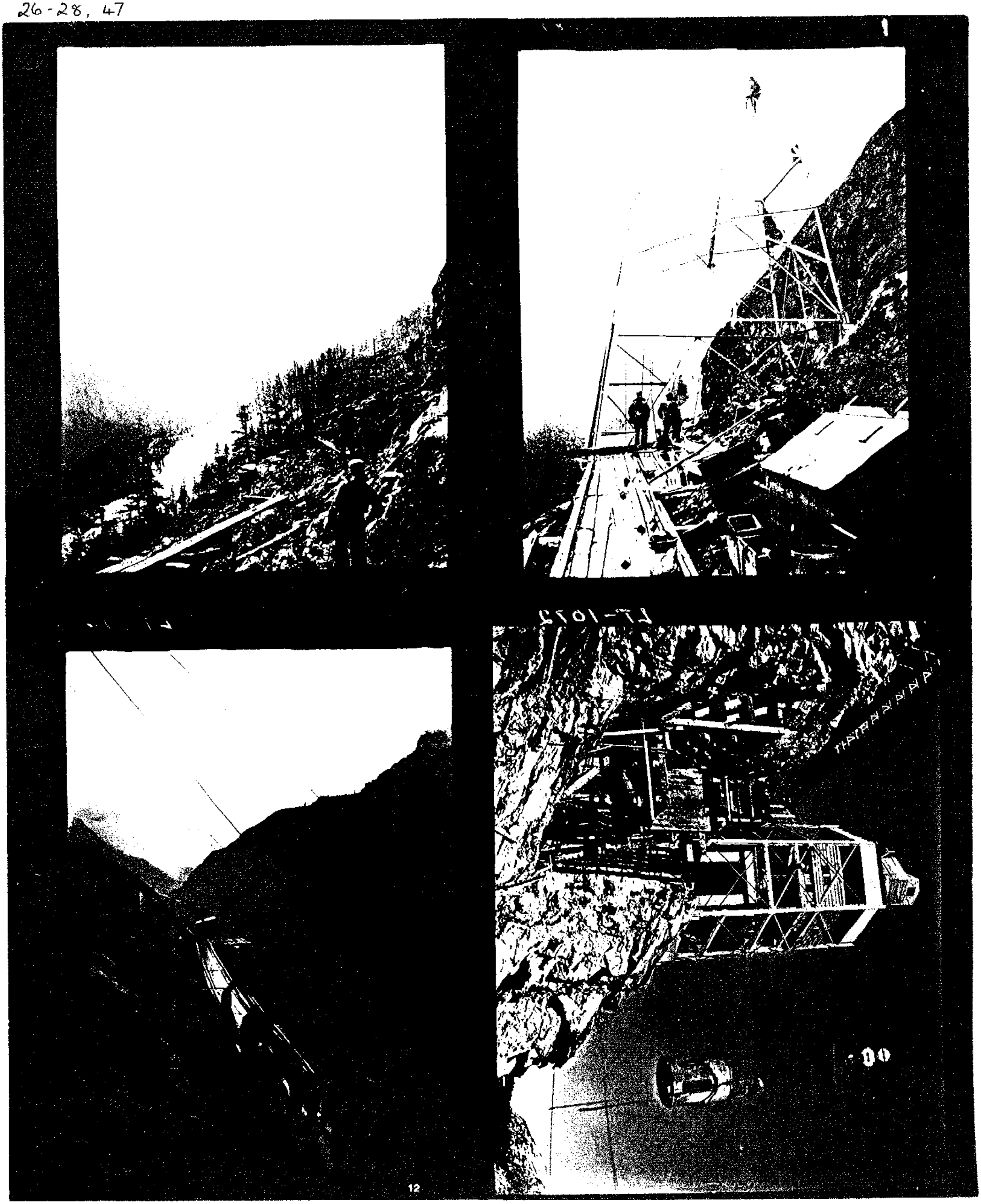

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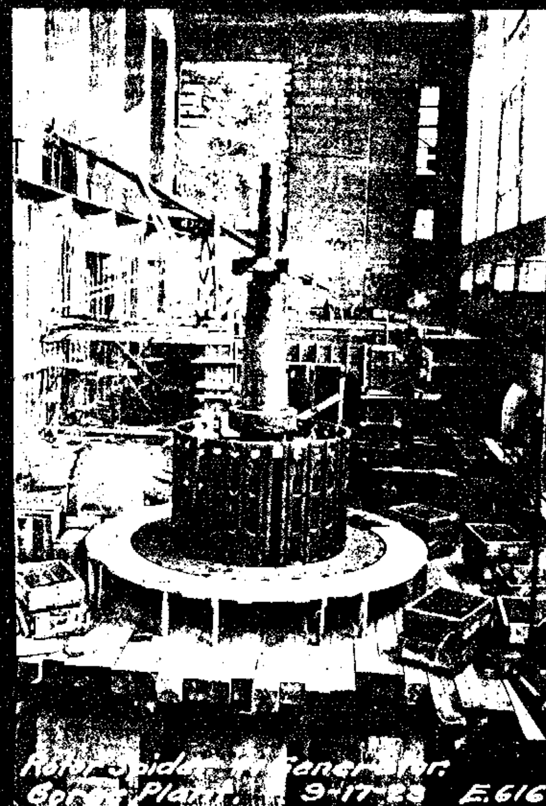

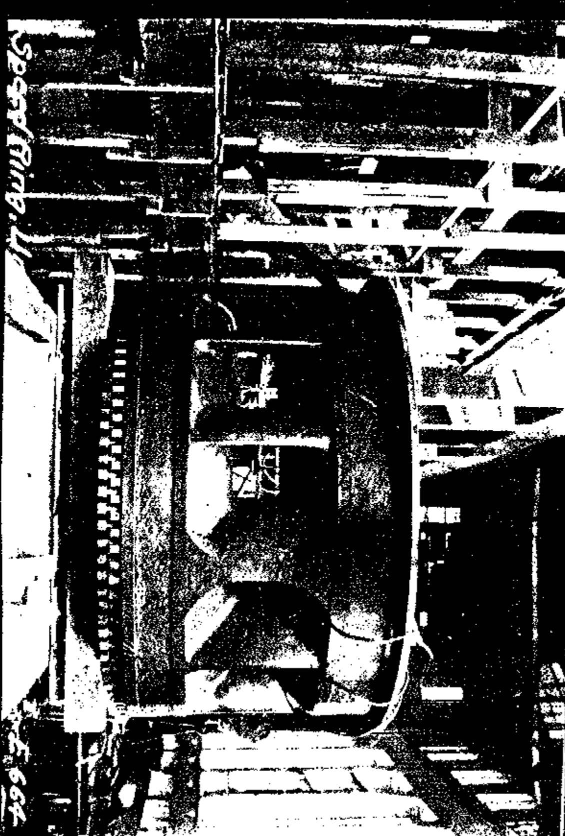

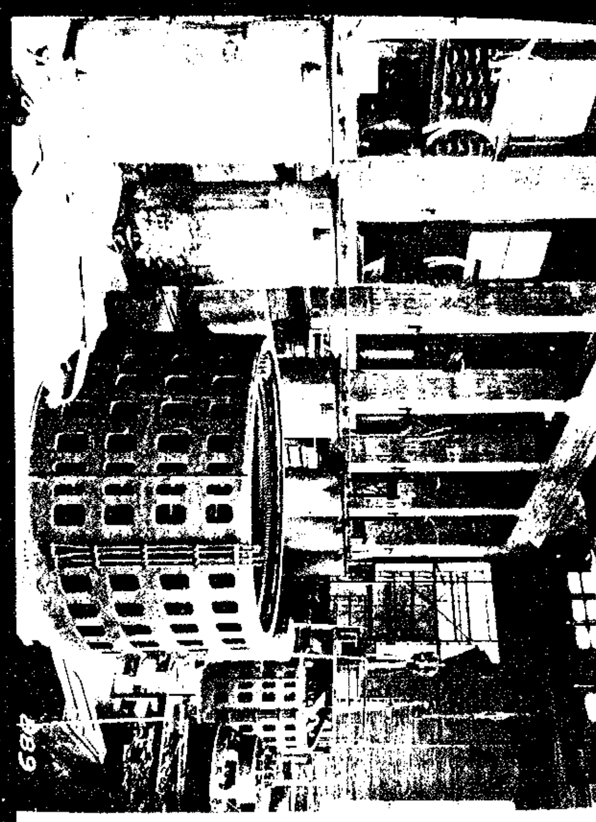

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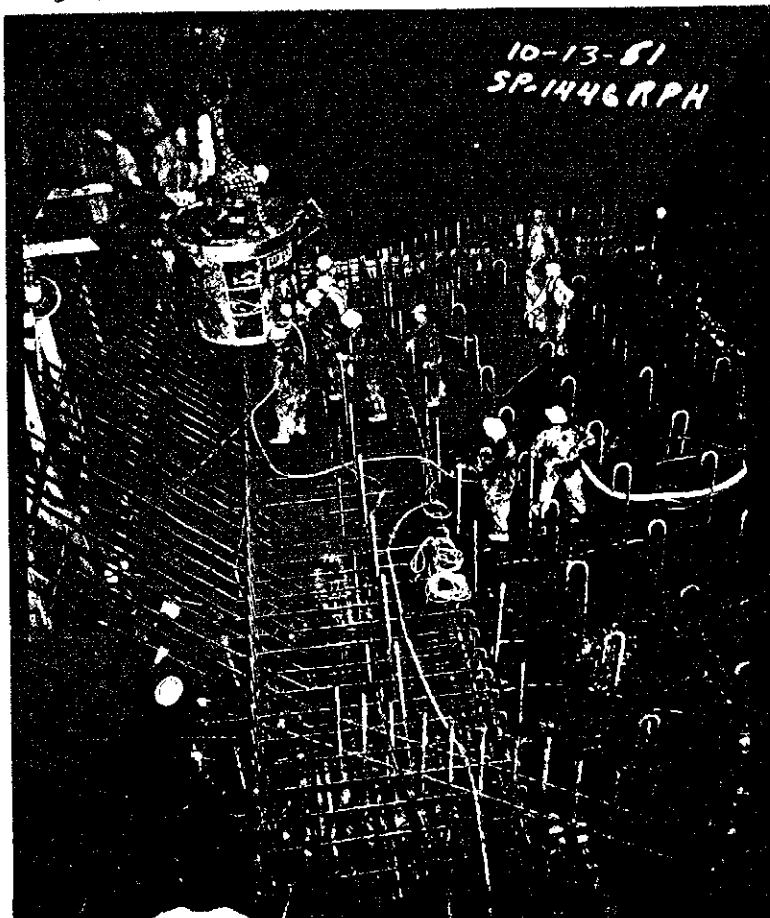

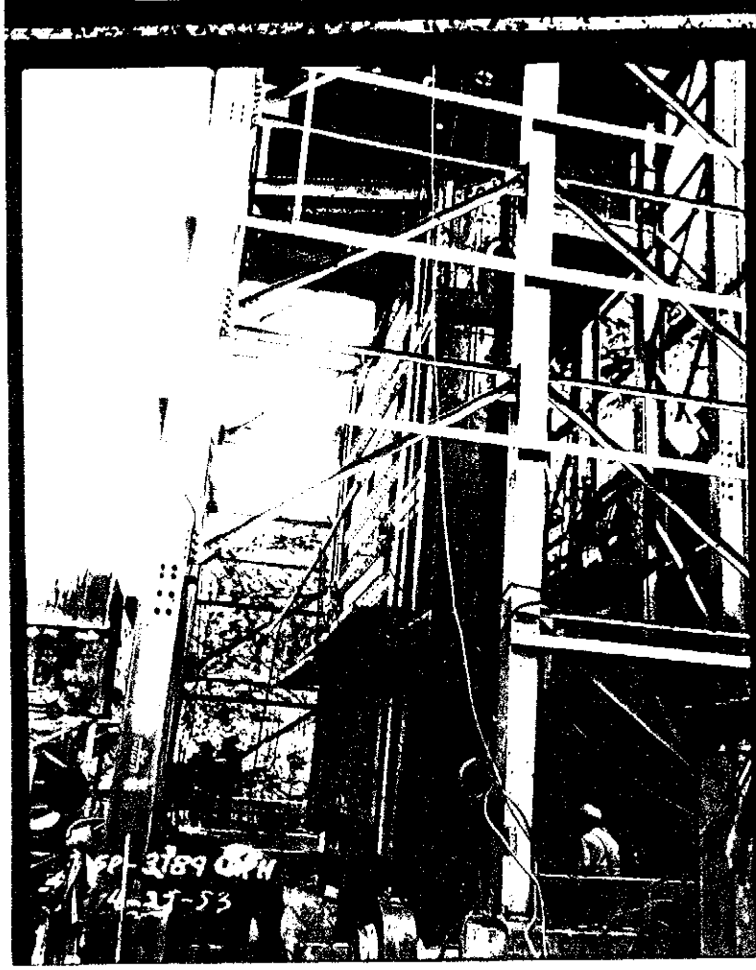

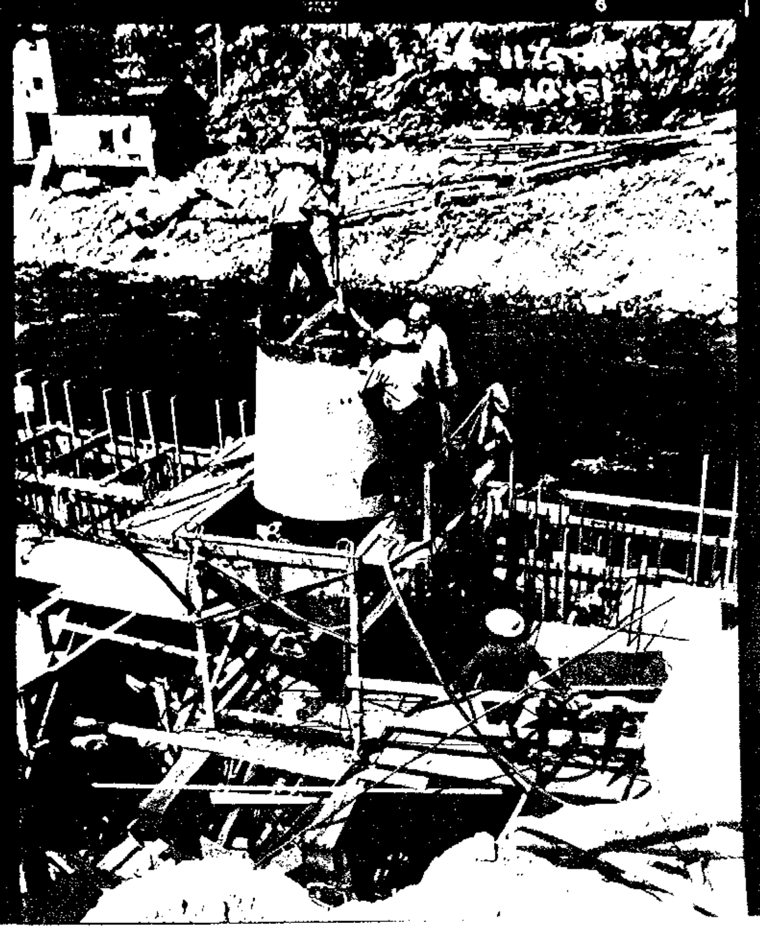

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